NORTH PACIFIC MARINE SCIENCE ORGANIZATION (PICES)
PROJECT ON *"MARINE ECOSYSTEM HEALTH AND HUMAN WELL-BEING"*

SCIENTIFIC PROGRESS REPORT YEAR 3 (APRIL 1, 2014–MARCH 31, 2015)

1. BACKGROUND

In December 2011, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, through the Fisheries Agency of Japan (JFA), approved funding for a 5-year PICES project on "*Marine Ecosystem Health and Human Well-Being*" (MarWeb; http://meetings.pices.int/projects/marweb). The project began in April 2012, with the ending date set as March 31, 2017. Its goal is to identify the relationships between sustainable human communities and productive marine ecosystems in the North Pacific, under the concept of fishery social-ecological systems (known in Japan as the "Sato-umi" fisheries management system). Considering that global changes are affecting both climate and human social and economic conditions, the project is expected to determine: a) how do marine ecosystems support human well-being? and b) how do human communities support sustainable and productive marine ecosystems? The project is also intended to foster partnerships with non-PICES member countries and related international organizations/programs. This contribution is from the Official Development Assistance (ODA) Fund and therefore, involvement of developing Pacific Rim countries in activities is required under this project.

The following organizational principles, agreed upon by MAFF/JFA and PICES, apply to the project:

- The project is expected to have strong connections and interactions with, and to involve and support the relevant activities of, the PICES FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) science program and PICES expert groups (Project Principle 3.1; Fig. 1).
- The project is directed by a Project Science Team (PST), co-chaired by Drs. Mitsutaku Makino (Fisheries Research Agency, Japan, mmakino@affrc.go.jp) and Ian Perry (Department of Fisheries and Oceans, Canada; Ian.Perry@dfo-mpo.gc.ca), with membership from PICES and non-PICES countries, as deemed appropriate (Project Principle 3.2).
- The PST Co-Chairmen are responsible for the scientific implementation of the project and annual reporting to MAFF/JFA and PICES Science Board. The report should be submitted to JFA within 120 days after the close of each project year ending March 31, and include a summary of the activities carried out in the year, with an evaluation on the progress made, and a workplan for the following year (Project Principle 3.3).

This progress report summarizes the activities carried out for Year 3 (FY 2014: April 1, 2014–March 31, 2015) and includes a workplan for Year 4 (FY 2015: April 1, 2015–March 31, 2016). The financial report for Year 3 is being submitted as a separate document simultaneously with this progress report.

2. WORKPLAN FOR YEAR 3

(1) Project Science Team meetings

- Organize two PST meetings, one inter-sessional (April 2014, Hawaii, USA) and in conjunction with the PICES 2014 Annual Meeting (October 2014, Yeosu, Korea).

(2) Case studies

In Indonesia

- Continue the multi-trophic aquaculture pond experiment and theoretical modeling of potential carrying capacity with Indonesian partners at Karawang experimental site, including follow-up site visit by a PST member;
- Hold a workshop in Pekalongan for manual development and transfer of lessons learned during Karawang experiments to a second location;
- Conduct the third social survey.

In Guatemala

- Design, and translate into Spanish, a social survey to understand the local situation (*e.g.*, why one community feels it is 'healthy' whereas adjacent communities feel they are not 'healthy');

- Carry out a social science assessment of “Sato-umi” with local partners;
- Design and conduct an IMTA experiment, with a focus on development of oyster aquaculture, processing and marketing, in collaboration with local partners.

(3) Human well-being surveys
- Analyze the data and review the results from the human well-being surveys conducted in Japan, Korea, United States, and Indonesia.

(4) Database
- Continue to develop the database including a bibliography of human-natural systems interactions and the well-being survey data and information from the Indonesia and Guatemala case studies;
- Start to build the on-line access system for sharing the contents of the database.

3. Progress of Year 3

3.1 Project Science Team meetings

The Project Science Team (PST) was established in August 2012 (Year 1) in order to review the scientific progress, and make recommendations for the implementation of the project. During Year 3, the PST membership was revised to better match the case studies that are being developed. As of March 2015, the PST membership includes 13 scientists: 4 from Canada, 3 from Japan, 2 from Korea and 3 from USA, and a representative from the PICES Secretariat (Table 1). A total of five PICES expert groups are represented on the Team: Section on *Hunan Dimensions* (S-HD), Section on *Climate Change Effects on Marine Ecosystems* (S-CCME), Section on *Ecology of Harmful Algal Blooms in the North Pacific* (S-HAB), Working Group on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors* (WG 28) and FUTURE Scientific Steering Committee (FUTURE SSC).

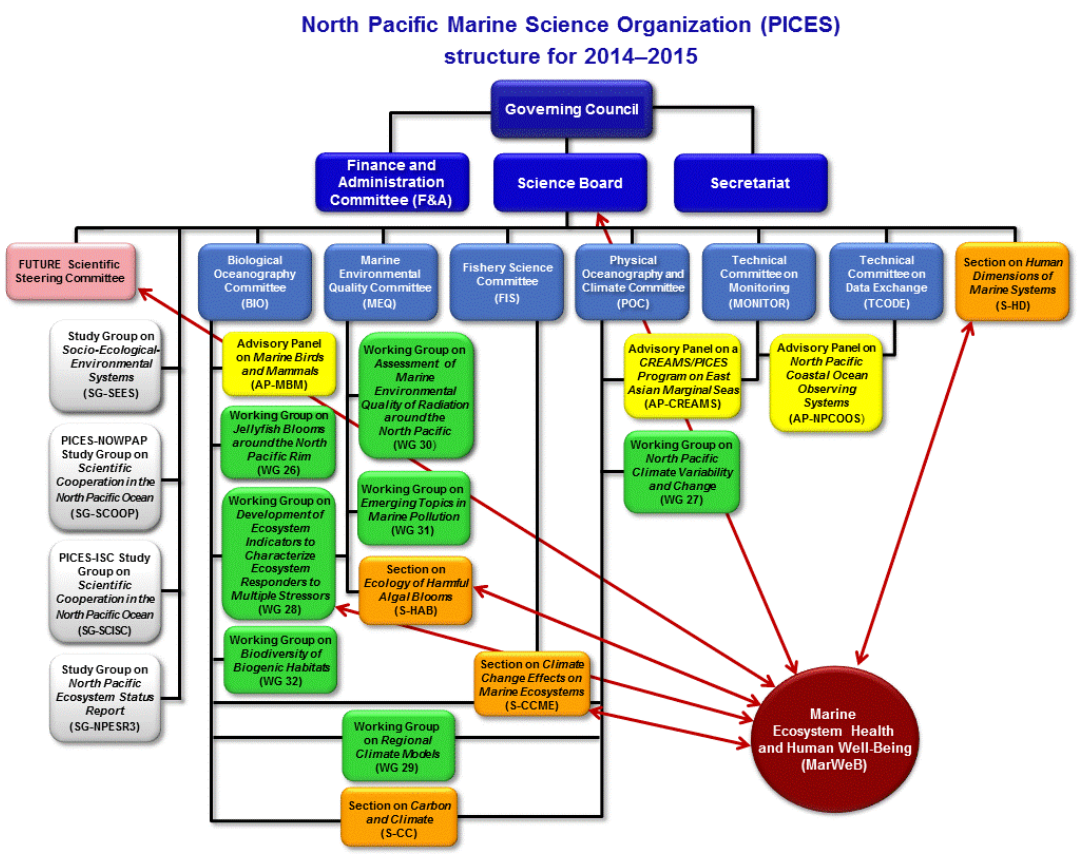

Fig. 1 PICES (North Pacific Marine Science Organization) structure for 2014–2015 showing links between the MarWeB project and expert groups.

Table 1 Membership of the Project Science Team (as of March 2015)

Name	Affiliation	Country/Group
Dr. Harold Batchelder	PICES Secretariat	PICES
Dr. Keith Criddle	University of Alaska, Fairbanks	USA/S-HD
Dr. Masahito Hirota	Fisheries Research Agency	Japan/S-HD
Ms. Juri Hori	Rikkyo University	Japan/S-HD
Dr. Suam Kim	Pukyong National University	Korea/S-CCME
Dr. Mitsutaku Makino	Fisheries Research Agency	Japan/S-HD
Dr. Grant Murray	Vancouver Island University	Canada/S-HD
Dr. Jongoh Nam	Korea Maritime Institute	Korea
Dr. Ian Perry	Department of Fisheries and Oceans	Canada/WG 28/FUTURE SSC
Dr. Thomas Therriault	Department of Fisheries and Oceans	Canada/FUTURE SSC
Dr. Vera Trainer	Northwest Fisheries Science Center	USA/S-HAB
Dr. Charles Trick	University of Western Ontario	Canada/S-HAB
Dr. Mark Wells	University of Maine	USA/S-HAB

In Year 3, two PST meetings were organized. The first meeting was held April 13, 2014, on the Kohala Coast, Island of Hawaii, Hawaii, U.S.A., in conjunction with the PICES FUTURE Open Science Meeting. The key objectives for that meeting were to: (a) plan for the Guatemala case study, (b) further develop the Indonesia case study, and (c) prepare the detailed workplan for FY 2014–2015. The goal of the second meeting held October 16, 2014, in Yeosu, Korea, in conjunction with the PICES 2014 Annual Meeting (PICES-2014), was to review progress made since the April meeting. A very successful topic session titled "*Ecological and human social analyses and issues relating to Integrated Multi-Trophic Aquaculture*" was convened at PICES-2014, with a large number of participants, including many not directly related to the MarWeB project. The reports from both PST meetings and other materials are available at http://meetings.pices.int/projects/marweb.

3.2 Case studies

3.2.1 Indonesia

Intensive shrimp aquaculture was developed in the Karawang area (3 hours from Jakarta) in the 1990s, and led to de-forestation, then marine pollution, shrimp mass-diseases, and ultimately to pond abandonment. The main issue is serious environmental degradation and land erosion due to removal of mangroves and building of coastal shrimp ponds. This has resulted in a current ecological system with intensive shrimp monoculture. The MarWeB project, in collaboration with the Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi, BPPT) of Indonesia, is conducting a study of the use of integrated multi-trophic aquaculture (IMTA; including seaweed, shrimp and fish) to demonstrate low emissions of deleterious materials into the natural environment and to provide alternative sources of protein and livelihoods for the local human population.

During Year 3, MarWeB activities in this case study included the following:

- Ecological systems
  - Workshop was convened to disseminate the concept of Sato-umi (Gempita) in Indonesia;
  - Pond experiment for IMTA was started;
  - Material circulation box-model for analysing the carrying capacity in the pond was constructed.
- Social systems
  - Basic social information (*i.e.*, statistics) was collected and analyzed;
  - Commodity chain analysis for IMTA products was revised;
  - Preliminary study was started based on an "analytic hierarchy process" (AHP) approach to support local decision-making. AHP is a structured technique for organizing and analyzing complex decisions;
  - Psychological survey analysis for well-being (*i.e.*, "well-being cube" analysis) was completed.

Ecological systems

Project activities in Indonesia are being conducted in collaboration with BPPT, which is a non-departmental government agency under the coordination of the Ministry of Research and Technology responsible for carrying out government duties in the field of assessment and application of technology. An experimental plan was developed for the MarWeB-sponsored Gempita (Sato-umi) pond experiment, which was started at the National Center for Brackishwater Aquaculture in Karawang, in August 2014. The main purpose of this experiment is to investigate the effect of IMTA on: (1) the economic return of pond operations, and (2) the water quality of the ponds, defined in terms of the (macro)nutrient concentrations of nitrate/nitrite, ammonia, and phosphate, in addition to other parameters (oxygen, phytoplankton, bacteria, *etc*.). The underlining hypothesis is that the addition of bivalves (*Anadara*) and seaweed (*Gracilaria*) into the aquaculture ponds of fish (*Tilapia* species) or shrimp will allow successful growth of all species, and decrease of macronutrient concentrations in the pond waters.

The optimal pond conditions for shrimp and fish are:
- a high phytoplankton biomass, including diatoms and green algae – phytoplankton provide additional food which enhances the flavor of the shrimp and fish;
- low light penetration which creates less stress for the shrimp and prevents the growth of seagrass in the pond.

For these reasons, nutrients (nitrate, phosphate) are added to high concentrations at the start, which helps to maintain high biomass of phytoplankton over the duration of the pond experiment.

The experiment was designed using four 4000 m^2 ponds at the National Center for Brackishwater Aquaculture: Pond 1 – Shrimp only, Pond 2 – Shrimp + *Gracilaria* + *Anadara*, Pond 3 – Fish (Tilapia) only, and Pond 4 – Tilapia + *Gracilaria* + *Anadara*.

Early results suggest the following:
1. There appears to be no negative effect on the shrimp or *Tilapia* weight gain in the ponds with the *Gracilaria* and *Anadara*. This was the main concern.
2. The replenishment of water in the *Tilapia* ponds from the reservoir is a potential source of nutrient variability, but concentrations in all ponds seem to track each other reasonably well (particularly NO_3/NO_2). The implication is that despite the considerable mixing (from paddle mixers), vertical gradients may be forming within the 1 m deep ponds. There also may be variation from site to site within the pond as the water circulates. Collecting vertically integrated samples was suggested.
3. The biggest problem was the high level of nutrient added to the ponds to generate enough plankton to prevent light from reaching the bottom of the pond.

Social systems

A revised commodity chain model was developed (Fig. 2). A 'system dynamics' model is being considered to explore the effects of changing parameters (*e.g*., in the commodity chain), and to examine the impacts of changes to various social parameters. An AHP (Analytic Hierarchy Process) approach is also being investigated to evaluate the choice of scenarios (*e.g*., the effects on outcomes of intensive culture, polyculture and IMTA approaches). The social survey for the "well-being cube" analysis was completed in Indonesia with the assistance of BPPT, and the results are now being analyses and compared with results from similar surveys in Japan, the United States, and Korea.

3.2.2 Guatemala

Much of Year 3 was focused on developing the MarWeB program in Guatemala. Two science themes have been adopted: (1) a focus on multi-trophic aquaculture for the natural science theme, and (2) a social science survey to understand how people and their livelihoods relate to the ocean.

Theme 1 involves collaborating with researchers at the University of San Carlos, Guatemala City, and with the Integral Fisheries Cooperative on the Pacific coast of Guatemala, to test the feasibility of growing, processing and marketing *Crassostrea gigas* (mangrove oyster) using an IMTA approach. The potential outcomes include increased income for coastal people, and improved health and well-being. Specific objectives are: assessing

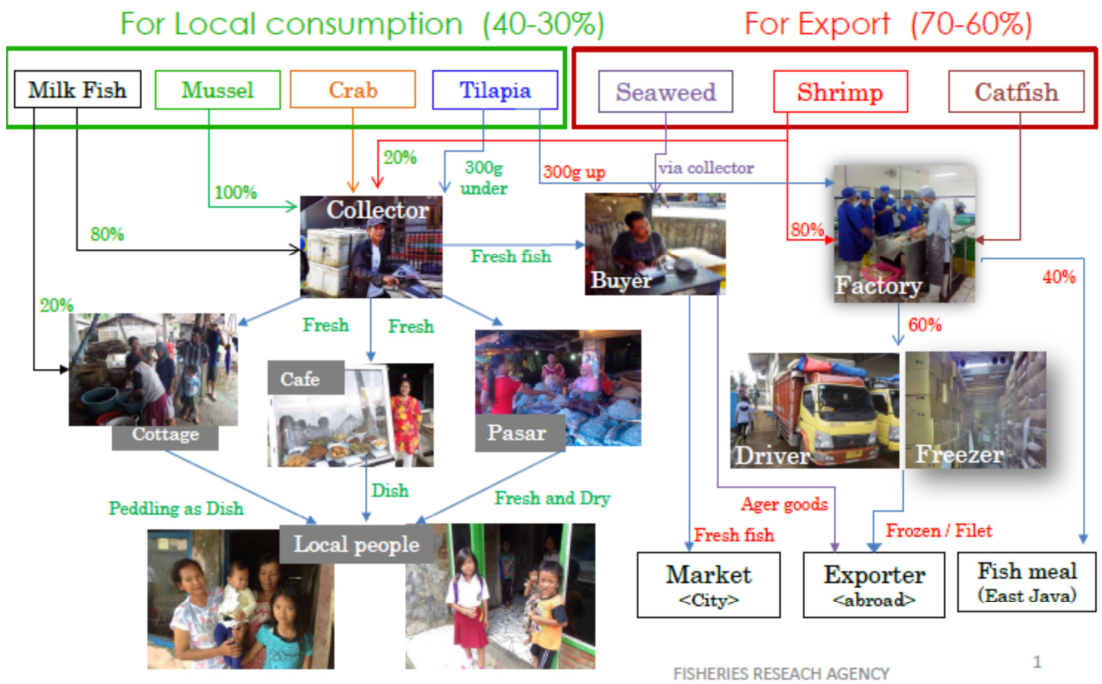

Fig. 2 Commodity chain of the IMTA products in Karawang area, Indonesia (revised).

the performance of the long-line shellfish culture system in La Barrona estuarine lagoons; determining yield potential of the culture system, including growth rates and time for mollusks to reach market size; evaluating shellfish survival rates during different phases of their growth and assessing mitigation methods against predation; adapting or developing culture practices appropriate for the management of the system; producing oysters that conform to the microbiologic standards of food safety; and assisting in finding suitable markets for the sale of the final product.

The project is now ongoing. For the first three months, sampling is being done every 2 weeks, and then will switch to once a month for the next 4 months. The monitored parameters are dissolved inorganic nutrients, dissolved oxygen, salinity, temperature, light transmission and phytoplankton. The monitoring is being carried out by students and faculty using equipment previously provided by the now completed PICES International Seafood Safety Project (ISSP) also funded by MAFF (Fig. 3). That PICES ISSP project provided training in identifying harmful algal species and measuring the toxicity of seafood exposed to toxic algae.

Fig. 3 Students and faculty from the Center for the Study of the Sea and Aquaculture (CEMA) of the University of San Carlos in Guatemala conducting water quality sampling for the oyster culture project and during currently ongoing harmful algal bloom monitoring efforts along the Guatemalan coast.

A mission to Guatemala City and two Pacific coastal towns (Las Lisas and Monterrico) was undertaken from February 26–March 7, 2015 to implement the social survey. These surveys were conducted with approximately 20 families in each of these two coastal towns, using a set of 34 questions with 5 possible answers from a computer to provide anonymity to the respondents. The survey asked questions such as how often the family buys seafood from the market, and whether the ocean provides enough food for the family. The surveys lasted approximately 1 hour, after which students conducted a follow-up interview to explore responses in more detail (Fig. 4).

Fig. 4 PICES MarWeB researcher (facing camera) conducting the follow-up semi-structured interview with families from Monterrico, Guatemala.

3.3 Analysis of human well-being in relation to environmental conditions

"Well-being" is defined by psychologists as involving peoples' positive evaluations of their lives such as positive emotions, engagement, satisfaction, and meaning. As identified in the UN Millennium Ecosystem Assessment, human well-being (HWB) has multiple constituents, including basic materials for a good life, freedom and choice, health, good social relations, and security. The constituents of well-being, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances. These factors are complex and value-laden. In the present study, HWB is being explored as a means to connect ecosystem services, human well-being, and freedom of choice and action, and in part to understand motivations for these choices and actions.

The "well-being cube" was developed to understand the structure of HWB in relation to the sea (*i.e.*, in a Sato-umi context). In Year 1, a survey of 1000 people in Japan was conducted to assess their relationships with the sea (Fig. 5). In Year 2, the same questionnaire was used to survey 500 people in Korea (Fig. 6) and the United States (Fig. 7). In addition to these three PICES member countries, a survey of 200 people was conducted, in collaboration with BPPT, in several Indonesian provinces to provide data for analyses of well-being in relation to the sea (Fig. 8). The well-being cube was built up with human-needs, and it shows distinctions among HWB structure of each country (*red* shows high-expectation and satisfaction need, *blue* is low-expectation and satisfaction need, *yellow* is high-expectation and low-satisfaction need, and *green* is low-expectation and high-satisfaction need). Also, a result from the SEM (Structural Equation Modeling) analysis showed the commonalities and differences to achieve "freedom of choice and action" among countries (Fig. 9).

Publication for a peer-review journal is now under preparation. Some initial findings indicate that all countries surveyed have similar general concepts of well-being in regards to the ocean; however, the specific understanding of how the ocean affects human well-being differ among these countries and, therefore, what makes for a desirable relationship between people and the sea is different among countries.

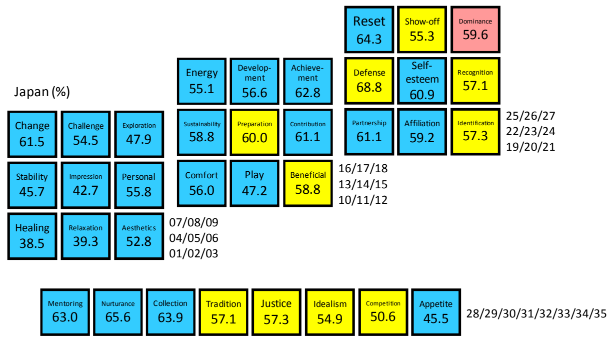

Fig. 5 Japan-CUBE (2012)

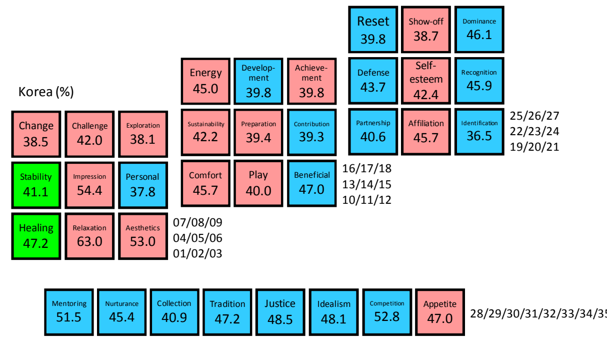

Fig. 6 Korea-CUBE (2013)

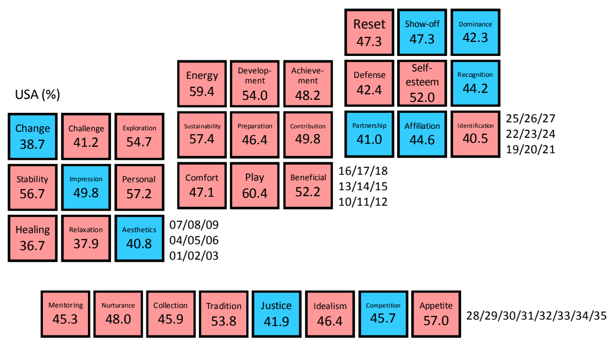

Fig. 7 United States-CUBE (2013)

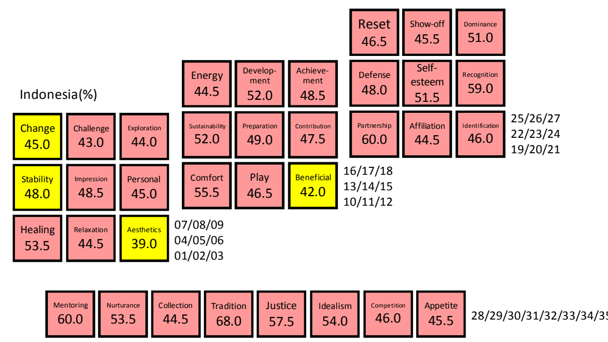

Fig. 8 Indonesia-CUBE (2014)

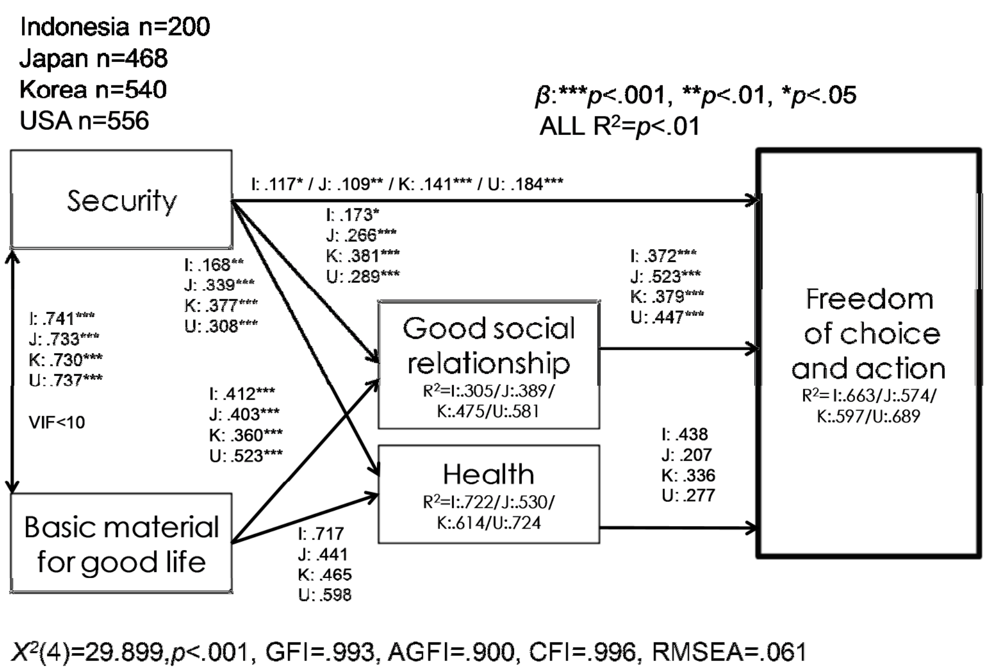

Fig. 9 Structural Equation Modeling of MA well-being items (multiple group) (2014).

3.4 Database

The database containing a bibliography of human-natural systems interactions and the well-being survey data from the Indonesia and Guatemala case studies is under development.

4. WORKPLAN FOR YEAR 4

(1) Project Science Team meetings

- Organize one Project Science Team meeting in conjunction with the PICES 2015 Annual Meeting (October 2015, Qingdao, China).

(2) Case studies

In Indonesia

- Complete the multi-trophic aquaculture pond experiment and theoretical modeling of potential carrying capacity with Indonesian partners at Karawang experimental site, including site visit by PST members;
- Organize a workshop to develop manual and identify lessons learned regarding human-environment interactions (Sato-umi) during pond experiments.

In Guatemala

- Continue the oyster project and expand from the estuary to the nearshore region to potentially include pearl oysters;
- Engage an eco-health expert to provide recommendations related to both aquaculture and economic health in the two study communities. This assessment will include recommendations for potential funding opportunities that will allow these communities to build upon our work and improve their overall health;
- Report to Guatemalan local people and PST on results of social science survey and aquaculture assessment.

(3) Human well-being surveys

- Continue analyses of the data and review the results from the human well-being surveys conducted in Japan, Korea, United States, Indonesia;
- Conduct web-based surveys in Russia and China.

(4) Database

- Continue to develop the database containing a bibliography of human-natural systems interactions and the well-being survey data and information from the Indonesia and Guatemala case studies.