



Title	TSUNAGARI: a new interdisciplinary and transdisciplinary study toward conservation and sustainable use of biodiversity and ecosystem services
Author(s)	Nakaoka, Masahiro; Sudo, Kenji; Namba, Mizuho; Shibata, Hideaki; Nakamura, Futoshi; Ishikawa, Satoshi; Makino, Mitsutaku; Yamano, Hiroya; Matsuzaki, Shin-ichiro S.; Yamakita, Takehisa; Yu, Xiubo; Hou, Xiyong; Li, Xiaowei; Brodie, Jon; Kanemoto, Keiichiro; Moran, Dan; Verones, Francesca
Citation	Ecological research, 33(1), 35-49 https://doi.org/10.1007/s11284-017-1534-4
Issue Date	2018-01
Doc URL	http://hdl.handle.net/2115/72485
Rights	The final publication is available at link.springer.com
Type	article (author version)
File Information	Nakaoka_ea_2018_EcolRes_HUSCAP.pdf



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1 Draft manuscript for the Special feature in Ecological Research “Biodiversity and Its
2 Ecological Functions in East-Asia and Pacific region: Status and Challenges”

3 Article type: "Current topics in ecology"
4

5 **TSUNAGARI: A new interdisciplinary and transdisciplinary study toward conservation**
6 **and sustainable use of biodiversity and ecosystem services**
7

8 Masahiro Nakaoka^{1,*}, Kenji Sudo^{1,2}, Mizuho Namba^{1,2}, Hideaki Shibata³, Futoshi Nakamura⁴,
9 Satoshi Ishikawa⁵, Mitsutaku Makino⁶, Hiroya Yamano⁷, Shin-ichiro S. Matsuzaki⁷, Takehisa
10 Yamakita⁸, Xiubo Yu⁹, Xiyong Hou¹⁰, Xiaowei Li¹⁰, Jon Brodie¹¹, Keiichiro Kanemoto¹²,
11 Dan Moran¹³, Francesca Verones¹³
12

13 ¹Akkeshi Marine Station, Field Science Center for Northern Biosphere, Hokkaido University,
14 1 Aikappu, Akkeshi, Hokkaido 088-1113, Japan

15 ²Graduate School of Environmental Science, Hokkaido University, Akkeshi Marine Station,
16 Field Science Center for Northern Biosphere, 1 Aikappu, Akkeshi, Hokkaido 088-1113, Japan

17 ³Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, Hokkaido,
18 Japan

19 ⁴Graduate School of Agriculture, Hokkaido University, Sapporo, Hokkaido, Japan

20 ⁵Research Institute for Humanity and Nature, 457 - 4 Motoyama, Kamigamo, Kita-ku, Kyoto,
21 Japan

22 ⁶Fisheries Research and Education Agency, 15F Queen's Tower B, 2-3-3 Minato Mirai, Nishi-
23 ku, Yokohama, Kanagawa, Japan

24 ⁷National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, Japan

25 ⁸Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho,
26 Yokosuka, Kanagawa, Japan

27 ⁹Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of
28 Sciences, 11A Datun Road, Chaoyang District, Beijing, China

29 ¹⁰Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, ChunHui Road
30 17#, Laishan District, Yantai, Shandong, China

31 ¹¹Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University,
32 Townsville, Australia

33 ¹²Faculty of Economics and Law, Shinshu University, 3-1-1, Asahi, Matsumoto, Japan

34 ¹³Department of Energy and Process Engineering, Norwegian University of Science and
35 Technology, 7491 Trondheim, Norway

36

37 *Corresponding author. TEL (0153) 52-2056; FAX : (0153) 52-2042

38 Email: nakaoka@fsc.hokudai.ac.jp

39 **Abstract**

40 The expanding economical activities have accelerated losses of biodiversity and ecosystem
41 services, which are especially pronounced in Asia. To find solutions to stop these losses, a
42 group of scientists studying both ecological and social sciences has launched an
43 interdisciplinary research network, entitled TSUNAGARI (Trans-System, UNified Approach
44 for Global And Regional Integration of social-ecological study toward sustainable use of
45 biodiversity and ecosystem services). The project is based on two main perspectives: (1)
46 integrating different disciplines of environmental research across multiple spatial scales, and
47 (2) evaluating the importance of ecosystem connectivity between land and ocean for
48 biodiversity and ecosystem services. The integrative studies have been started as follows: (1)
49 integrating global-scale analyses of biodiversity and economy by developing GIS-based
50 footprint analysis, (2) establishing the link between the studies of local good practices of
51 ecosystem management and life cycle assessment on ecosystem good and services, (3) linking
52 local-scale ecosystem studies to decision making processes for sustainable society by multiple
53 stakeholders, and (4) upscaling local analyses of ecosystem processes to broad-scale analyses
54 of ecosystem patterns. The proposed approaches are considered effective to solve problems
55 that impede conservation of biodiversity and sustainable use of multiple ecosystem services in
56 various situations although we also find some gaps such as regional biases in biodiversity data
57 and involvement of different types of stakeholders. By overcoming the major bottlenecks, we
58 believe the new integrated approaches will promote conservation and sustainable management
59 of biodiversity and ecosystem services research, and contribute to advance decision-making
60 processes from local communities to international levels.

61

62 **Keywords:** Coastal ecosystem, Cross-scale integration, Eastern and southeastern Asia,

63 Ecosystem connectivity, Social-ecological system

64

65 **Introduction**

66

67 The expanding economical activities by human have caused accelerated losses of biodiversity
68 and multiple ecosystem services (i.e., provisioning, regulating, cultural and supporting
69 services; Millennium Ecosystem Assessment 2005) through rapid land/sea use changes. This
70 is aggravated by global climate change, which affects both terrestrial and marine ecosystems
71 in multiple ways, not only by direct effects of temperature rise, but also by increase in intense
72 stormy conditions, ocean acidification and sea level rise (Harley et al 2006; IPCC 2014).
73 Meanwhile, analyses of ecological footprints have revealed that increasing economic demands
74 by developed countries for provisioning services are among the main causes of biodiversity
75 loss in developing countries (Lenzen et al.2012; Weinzettel et al. 2013). The combined effects
76 of climate change and global economic activities can lead to further degradation both of
77 terrestrial and marine ecosystems, and to economic disparity in local human communities. In
78 order to reverse this trend, there is an urgent need to find better way to conserve and
79 sustainably use biodiversity and ecosystem services. Some international efforts have been
80 initiated, e.g., by setting Sustainable Development Goals (United Nations 2015), and by
81 assessing the status of global biodiversity and ecosystem services by Intergovernmental
82 Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al. 2015),
83 although local activities such as establishing environmental stewardship cultivated through
84 co-design, co-production and co-delivery activities are still not well-established in most
85 regions of the world.

86 Since the publication of the Millennium Ecosystem Assessment (2005), the recognition
87 and understanding of the global state of biodiversity and ecosystem services, their drivers, and
88 their dependence on social and economic activities have improved. At the same time, the need

89 for a more systematic approach for promoting interdisciplinary research on social-ecological
90 systems has been highlighted (Cumming 2007; Carpenter et al. 2009; Ostrom 2009; Pereira et
91 al. 2010). However, scientific knowledge is still limited for planning and executing effective
92 management activities at both global and local scales. Major bottlenecks in the ecological
93 sciences include the lack of fine-resolution information of the distribution of biodiversity at
94 each locality (Jetz et al. 2012; Meyer et al. 2015), a great degree of variability in biodiversity
95 and ecosystem services across multiple environmental gradients (Koch et al. 2009; Nakaoka
96 et al. 2014; Nordlund et al. 2016), and interrelationships (trade-offs) among multiple
97 ecosystem services (e.g., between provisioning and regulation services (Carpenter et al. 2009;
98 Maas et al. 2016). As for social science, understanding for sustainable use of natural resources
99 use are often limited due to the lack of scientific knowledge about the consequence of
100 economic activities and consumption on the loss of biodiversity and ecosystem services, and
101 due to insufficient communication among scientists, stakeholders and local citizens with
102 different interests and demands (Dornelas et al. 2014).

103 Some of the above-mentioned problems share the same properties both in ecological
104 and socioeconomic studies. Firstly, processes determining biodiversity and multiple
105 ecosystem services, and decision making of their use are affected by nested, hierarchical
106 structures; i.e. processes at broader spatial scales (e.g. climate variation and global economy)
107 regulate processes at small spatial scales (e.g., species interaction in biological communities,
108 and human interactions in local social communities), and vice versa (Peterson and Parker
109 1998; Noda 2004). Secondly, the connectivity of ecosystems between terrestrial and marine
110 environments affects dynamics of biodiversity and multiple ecosystem services and decision-
111 making processes at the community level (Polis et al. 1997; Waterhouse et al. 2016; Fang et
112 al. in press). Previous studies on social-ecological systems cannot address these points

113 sufficiently, although the importance of integration has been recognized recently (Cumming
114 2011). It is likely that those points are attributable to many reasons originated from various
115 stakeholders. At this stage, we need to identify which problems should be solved first and
116 which data and information scientists can appropriately provide decision makers. Thus,
117 interdisciplinary and transdisciplinary collaboration between stakeholders and researchers are
118 critically required for successful co-design, co-production and co-delivery of knowledge
119 building. This is especially true in Asia where values of biodiversity and ecosystem functions
120 of natural ecosystems are estimated to be the highest in the world (Stuart-Smith et al. 2013;
121 Dickson et al. 2014), but where detailed information of biodiversity and ecosystem services,
122 as well as social-ecological studies have not been well organized as yet (Nakaoka et al. 2014,
123 Kim et al. in press).

124 The establishment of interdisciplinary and transdisciplinary research networks
125 consisting of both ecological and social scientists, as well as stakeholders and decision-
126 makers, are necessary to solve the environmental problems we are facing. As an attempt, a
127 group of scientists from various fields of environmental studies, both in ecological and social
128 sciences has launched a research network, entitled TSUNAGARI (Trans-System, UNified
129 Approach for Global And Regional Integration of social-ecological study toward sustainable
130 use of biodiversity and ecosystem services), with the support of the Belmont Forum
131 (www.belmontforum.org). The Japanese word ‘tsunagari’ means connectivity, link and
132 relationship, which we intend to build among scientists in different disciplines and among
133 scientists, practitioners and stakeholders involving conservation of biodiversity and
134 sustainable use of ecosystem services. The participants differ greatly in their background of
135 expertise, ranging from ecologists studying community and ecosystem ecology,
136 biogeochemists and geographers studying land/sea use changes, fisheries scientists studying

137 local fisheries practices, fisheries management and policies, and to industrial ecologists
138 studying global economy and sustainable sciences. Among various types of ecosystems,
139 scientists studying coastal zones (e.g. wetlands and nearshore habitats) predominate in our
140 group partly because one of our primary focuses is ecosystem connectivity between land and
141 ocean for which most previous studies have been made in coastal zones.

142 During the two-year duration of TSUNAGARI project, we hold three workshops (at
143 Ishigaki Island, Japan in May 2015, at Yantai and Yellow River Delta, China in April 2016
144 and at Kyoto, Japan in October 2016) to thoroughly discuss what types of interdisciplinary
145 and transdisciplinary collaborations we could start to solve the above-mentioned problems.
146 This concept paper is one of the outputs of TSUNAGARI activities. We first explain two
147 main perspectives on the new interdisciplinary and transdisciplinary studies aiming to achieve
148 (1) cross-scale, and (2) cross-ecosystem integrations. We then introduce ongoing case studies
149 by TSUNAGARI participants demonstrating effective scientific approaches based on the
150 integrated collaboration, specially focusing on coastal ecosystems in Asia and the world.
151 Finally, we consider directions for future integrative studies by pointing out the gaps in our
152 current knowledge. Our ultimate goals of the collaboration are to evaluate the current status
153 and conditions of biodiversity, ecosystem services and their use by human communities in
154 various types of ecosystems connected to each other, to establish which knowledge will be the
155 baseline to predict future changes based on different scenarios on climate changes and
156 development of human society, and to provide solutions to the problems of decision-making
157 processes for sustainable use of biodiversity and multiple ecosystem services locally,
158 regionally and globally.

159

160 **TSUNAGARI Perspective 1: Integrating different disciplines of environmental research**
161 **across multiple spatial scales**

162

163 Various types of interdisciplinary studies linking ecological and social studies have been
164 ongoing since the last decade (Cummings 2007, 2011; Carpenter et al. 2009; Maas et al.
165 2016). However, it is still least understood how integrated research should focus on the issue
166 of multiple spatial-scale dependency which is important both in the natural ecosystems and
167 human decision-making processes (Fig. 1).

168 For the side of ecological studies, it has been acknowledged that processes affecting
169 biodiversity and ecosystem services are determined by multiple factors operating at
170 differential scales (the right side of Fig. 1). In both terrestrial and marine ecosystems, climate-
171 driven abiotic factors shape global patterns of biodiversity and ecosystems through variation
172 in temperature, precipitation and oceanic current regimes. For biotic factors, evolutionary and
173 biogeographical processes such as restriction and release of certain types of organisms with
174 changes in barriers (due to continental and oceanographic current shifts) determine global
175 patterns of biodiversity over very long time-scales (Briggs 1995). At the intermediate scale
176 (e.g., 10 to 1000 km scale), factors related to geographical settings of the regions, such as
177 altitude, ocean depth, monsoon winds and coastal upwelling determine vegetation or biomass
178 of dominant organisms in each ecosystem (Roughgarden et al. 1988; Palumbi and Pinsky
179 2014). At the small spatial scales (e.g. 1 to 1000 meter or smaller scales), classical studies in
180 1960-70's already clarified that local disturbances such as wind and wave forces, as well as
181 biological interactions among species such as predation and competition interfere with the
182 processes determining biomass and productivity of organisms at different trophic levels
183 (Connell 1961, 1978; Paine 1966; Dayton 1971). Previous studies on ecology already

184 highlighted the multiple scale issues causing nonlinear, complicated dynamics of ecosystems
185 (Peterson and Parker 1998; Noda 2004; Yamakita et al. 2011).

186 The same type of scale dependency is also important when we consider multiple effects
187 of human-induced stresses to natural ecosystems. In coastal ecosystems for example,
188 overexploitation of some specific resources, eutrophication and coastal development occur at
189 relatively small spatial scales, whereas climate-related changes such as temperature rise and
190 ocean acidification are ongoing at broader spatial scales. Most importantly, concurrent
191 impacts of multiple drivers cause synergetic and unpredictable effects on biodiversity and
192 ecosystem services (Hughes et a. 2003). Examples include the combined effect of temperature
193 rise, ocean acidification and oxygen depletion on marine benthic animals in which the
194 organisms impacted by multiple stresses suffer more severely than those exposed to only one
195 type of stressor (Pörtner and Langenbuch 2005; Harvey et al. 2013). Likewise, interacting
196 effects of temperature rise and alteration of coastlines by concrete walls and blocks may
197 increase the invasion of non-native species, which are generally more resistant to heat and
198 adapted to human-altered habitats (Stachowicz et al. 2002; Lenz et al. 2011).

199 Scale dependency is also important in social studies on environmental problems (the
200 left side of Fig. 1). Firstly, decision making processes toward sustainable ecosystem
201 management are affected by multiple sectors operating at different spatial and political scales.
202 In the case of Japan, environmental policies are made and governed at three levels of
203 organizations; i.e., local governmental units (LGU; cities, towns or villages; a total of 1718, as
204 of April 2017; <http://www.soumu.go.jp/kouiki/kouiki.html>, as on April 9th, 2017), prefectures
205 (a total of 47) and the national government. Decision making at the national government is
206 also affected by international activities and treaties. Secondly, with the rapid expansion of
207 international trade, local economic activities are more and more affected by global market

208 dynamics even in a small village. Thus, the analyses of regional research elucidating local
209 decision-making processes should be linked with global economic analyses.

210 As multi-spatial scale issues are prominent both in ecological and social studies, the
211 development of interdisciplinary and transdisciplinary science should also consider the nested,
212 hierarchical structures of processes as depicted in Fig. 1. During the three workshops of
213 TSUNAGARI, we discussed the most plausible ways of integration across different
214 disciplines and across different scales. Many pathways of integrated approaches were
215 discussed, depending on research interests of participants (arrows in the middle parts of Fig.
216 1) although we recognized that it is virtually impossible to include all the integration into one
217 single study. We thus decided to proceed with listing up partial integration of different
218 combination of interdisciplinary studies and tried to evaluate which approaches are most
219 effective to solve different types of environmental problems (Fig. 2). The integration of
220 social-ecological study both at global and local scales was firstly discussed to be practical and
221 useful (Areas 1 and 3 in Fig. 2, respectively). For the integration of spatial scales, studies can
222 be initiated for both social and ecological systems (Areas 2 and 4 in Fig. 2, respectively). We
223 then started partial collaboration on these subjects, which are explained in the case studies
224 below.

225

226 **TSUNAGARI Perspective 2: Evaluating the importance of ecosystem connectivity on**
227 **biodiversity and ecosystem services, and on interactions among different stakeholders**
228 **within a watershed**

229

230 The organisms living in natural ecosystems are affected not only by the processes generated
231 within each ecosystem, but also by factors and drivers coming from outside the ecosystems,

232 either by physical, chemical or biological processes (Gregory et al. 1991; Polis et al. 1997;
233 Nakamura et al. 2004). Ecosystem connectivity is especially important for biodiversity in
234 marginal habitats (ecotones) such as riparian forests/grasslands, saltmarshes and estuaries
235 (Fig. 3).

236 The effects of ecosystem interactions are quite diverse, and multiple types of
237 interactions occur concurrently at different spatial scales (as discussed in the previous
238 section). Along the coastal areas of eastern Hokkaido, Japan, for example, three types of
239 ecosystem interactions are identified that are important in determining ecosystem functions
240 and processes both on land and ocean. At the broadest spatial scale (10-100 km²), summer sea
241 fog caused by rapid cooling of warm southern monsoon by the cold Oyashio current cools
242 coastal area which is ca. 5 °C cooler than in the inland. The cooling makes the types of forest
243 vegetation and agriculture in this area very specific compared to other part of Hokkaido
244 (Takeuchi et al. 1982; Sawai 1988; Abe 1996; Iyobe et al. 2003). At the medium scale (1-10
245 km²), effects of terrestrial land use change from forest to agriculture affects water chemistry
246 of rivers running each watershed, which can ultimately lead to changes in water quality at
247 estuaries and nearshore sea (Mukai et al. 2002; Mukai 2005). Finally, at the smallest scale (<
248 1 km²), waterfowl (herons) and fish (salmons) transport marine organic matters (their prey
249 and themselves) to river and terrestrial areas, which locally affects community structure of
250 forest and predatory bird behaviors (Ueno et al. 2006; Kamauchi et al. 2012; Honda et al.
251 2014). These examples show that land and ocean are ecologically connected by multiple
252 (physical, chemical and biological) processes that operate at various spatial scales.

253 These interactions among ecosystems are affected by various stressors associated with
254 human activities. One of the best known examples is the problem of sediment and nutrient
255 discharge from watersheds that causes deterioration of marine ecosystems. This is particularly

256 evident in tropical and subtropical regions. In Okinawa, after the reversion to Japan in 1972,
257 extensive agricultural development resulted in a significant increase in sediment discharge to
258 coastal waters, which has caused the degradation of freshwater and coastal ecosystems and
259 biodiversity (Omija 2004). In the Great Barrier Reef (GBR) of Australia, sediment derived
260 from increased erosion associated with beef cattle grazing and discharged via large rivers
261 affect coral status (Bartley et al. 2014). In the northeastern Philippines, combined effects of
262 sediment and nutrient runoff, and water pollution by excess fish aquaculture caused
263 significant losses of seagrass bed and its biodiversity (Tanaka et al. 2014).

264 Compared to ecosystem connectivity, social connectivity of human communities
265 among different parts of the watershed have been less studied and understood. The patterns of
266 interrelationships among human communities within forest, river basin and coastal areas have
267 been documented in some studies on environmental sociology, as represented by some
268 examples such as the conflict among local communities over water resources in relation to
269 land use change, impacts of intensified agriculture use of land on the water quality and fish
270 catch in the downstream, and the negative effects of overexploitation of salmons in the coastal
271 areas on the river fisheries in the upstream (Just and Natanyahu 2012; Qiu and Turner 2013;
272 Lange et al. 2014). Such conflicts have led to minimal progress on managing sediment and
273 nutrient discharge to the GBR from agriculture despite significant management expenditure
274 (Brodie and Pearson 2016).

275 One of the difficulties in the study of interactions among different stakeholders in a
276 watershed is that watershed boundaries do not always agree with that of local governmental
277 units, making the co-design of decision-making processes and their co-management difficult
278 to establish. Another problem lies in that fact that a lot of ecosystem goods and services are
279 now transported over long distance regardless of local interactions within a watershed. Before

280 the onset of globalization, it was a common practice by all human communities in coastal
281 zones to carry out both agriculture on land and fisheries in rivers and nearshore seas. In such a
282 case, solutions related to the conflict between land and sea uses could be brought under the
283 consensus within each community. Nowadays, however, agriculture and fisheries (including
284 aquacultures) have been more and more specialized and separated from each other, with
285 different types of stakeholders getting involved in the use of terrestrial and coastal ecosystem
286 services not only for provisioning services but also for cultural services such as leisure and
287 ecotourism uses. Researchers and decision-makers alike still struggle with fully understanding
288 of the implications of such intensified use of the connectivity and functioning of local
289 ecosystems.

290 In the TSUNAGARI workshops, we discussed how we can plan and conduct studies on
291 ecosystem connectivity taking both social and ecological systems into account. We
292 considered and planned two types of researches with different approaches. The first study
293 conducts social-ecological system surveys by incorporating all the ecological and social
294 components within a local watershed consisting both of terrestrial and marine ecosystems.
295 The second study examines and forecasts changes in ecosystem processes in a watershed
296 based on different scenarios on land/sea use changes by multiple stakeholders. These
297 integrated studies are explained in more detail in the third subsection of the case studies
298 written below.

299

300 **Case studies in integration**

301

302 As mentioned above, we initiated several partial integrations between participants with
303 different specialties to build new interdisciplinary and transdisciplinary sciences to achieve

304 our perspective goals. In this section, we present four of these integration efforts via case
305 studies that link different disciplines of social-ecological studies over different scales (Fig. 2),
306 and different types of ecosystems within a region.

307

308 1. Linking global-scale analyses of biodiversity and economy

309

310 Expansion of human economic activities affect global biodiversity and ecosystem services
311 directly by destroying and altering habitats and indirectly by changing climate. For the latter,
312 many studies have been trying to forecast future changes in biodiversity and ecosystem
313 functions based on the climate scenarios by IPCC (Yara et al. 2012; Beaugrand et al. 2015;
314 Molinos et al. 2016). For the former, recent progress of the global footprint analysis enables
315 us to analyze the effects of global economic activities and trade on biodiversity and various
316 types of ecosystem services such as water, carbon and nitrogen (Hertwich and Peters 2009;
317 Hoekstra and Mekonnen 2012; Galloway et al. 2014; Oita et al. 2016).

318 Global footprint analysis provides a way to understand which countries are responsible
319 for greater or less environmental impacts in other world regions, such as carbon emissions,
320 nitrogen increase and biodiversity loss. This is based on a global scale analyses of world trade
321 (input-output) data. For the biodiversity footprint, Lenzen et al. (2012) and Moran et al.
322 (2016) showed how seriously the economic activities by the developed countries increase the
323 extinction risk of endangered species in developing countries through habitat loss.

324 Although an already powerful tool, the current global footprint analysis still has some
325 limitations. First, global analyses of footprints to date have been primarily based on data and
326 statistics collected at national and international levels (such as in world-trade statistics).
327 However, a large variation exists in the spatial patterns of biodiversity, the vulnerability of

328 species to change, available ecosystem services, and economic activities. A resolution at the
329 country-level analyses is thus not fine enough to fully understand the impact of economy on
330 biodiversity loss of each specific area or species. To overcome this point, it is promising to
331 utilize spatially-explicit GIS data of the distribution and abundance of species. A recent study
332 by Moran and Kanemoto (2017) extend their footprint analyses to include GIS data on IUCN
333 red listed species, and successfully depicted the footprints at very fine resolution over the
334 whole globe (Fig. 4). Their analyses clearly showed how much impacts are given to each
335 biodiversity hotspot of the world by which types of specific human activities. Another study
336 quantified the potential loss of species from several taxonomic groups for multiple impacts
337 (climate change, eutrophication, acidification, land and water use) from global trade (Verones
338 et al. 2017), thus showing the consequences of our resource consumption for ecosystems on a
339 global level.

340 The second problem, which is less appreciated by socioeconomic scientists, is the fact
341 that the indicators useful in evaluating biodiversity and ecosystem service change at fine
342 resolution are still limited in terms of the data type and accuracy for most species and
343 ecosystems. In the studies of global biodiversity footprint mentioned above, the data used
344 were on distribution range and status of threatened species given by IUCN database on red list
345 species (Lenzen et al. 2012; Moran and Kanemoto 2017). Even though it is an excellent
346 example for using the fine-resolution, but broad-extent data on biodiversity, such data are
347 available only for relatively well-studied species (such as mammals and birds). Even for these
348 species, some information is based on non-quantitative observation such as knowledge by
349 local experts. It is especially true for marine species, where large information gaps still exist
350 in the distribution and thus cannot be evaluated adequately by the red list categories.

351 This problem will be overcome by the collaboration between researchers on footprint
352 analyses and scientists studying species distribution models using the mega-database of
353 biodiversity such as GBIF (www.gbif.org) and OBIS (www.iobis.org). For the marine
354 biodiversity research, recent increase in biodiversity data, and the development of species
355 distribution models will enable us to estimate global biodiversity patterns and its future
356 changes in finer resolution. Indeed, the resolution of the species distribution models of some
357 marine taxa increased from 10 degree latitude/longitude grid in 2010 (Tittensor et al. 2010) to
358 0.5 degree in 2015 (Klein et al. 2015). By utilizing these fine-resolution data on biodiversity,
359 evaluation of important areas for selecting marine protected areas has already been conducted
360 (Yamakita et al. 2017). It is now ready to carry out spatially explicit analyses of global
361 footprint for more target species, which results will offer valuable information to various
362 stakeholders and decision makers.

363

364 2. Linking studies of local practices and global economic analyses

365

366 Collaboration of scientists with local stakeholders who actually manage the status of
367 ecosystems are essential to achieve effective conservation of biodiversity and ecosystem
368 services. The practical activities based on “co-design, co-production and co-management”
369 have been ongoing and the international research community promotes such efforts under the
370 name of “transdisciplinary research” (Lang et al. 2012; Brandt et al. 2013).

371 One such transdisciplinary research framework has been established to achieve
372 sustainable use of marine ecosystem services in coastal areas of Asia, named as “Area
373 Capability Cycle (ACC)” (Ishikawa and Watanabe 2015). In this study, scientists collaborate
374 with local stakeholders such as fishermen and managers in local governments first by

375 transferring knowledge on values of natural capitals and ecosystem services, and then discuss
376 and determine effective and efficient methods of economic activities for sustainable use of
377 ecosystem services by round-table meetings. Established plans are to be executed in the real
378 field with PDCA (plan-do-check-act) cycle, which will facilitate the conservation of
379 biodiversity and ecosystems, as well as the sustainable use of ecosystem services by the
380 stakeholders concurrently (Fig. 5).

381 One successful case study of ACC is found in a fishery community of Rayong, Gulf of
382 Thailand. Here, traditional small-scale fisheries have long been conducted by individual
383 fishers, which sometimes lead to overexploitation of some specific resources, and to low yield
384 despite long operation time. However, after an ecological assessment of fish stocks (status of
385 provisioning services) by scientists, local fishers changed their fishery practices to conduct a
386 large stationary net fishery by group operation, which resulted in more yield in less operation
387 time (i.e., more income in more sustainable way). The new practice also enhanced
388 communication (good relationship) among fishers and their responsibility to manage the
389 sustainable ecosystem services (Ishikawa et al. 2015).

390 However, it remained unknown whether the established sustainable fishery was in fact
391 “environmental-friendly” in terms of consumption of materials and energy. For example, if a
392 new fisheries practice uses more materials from the world and if it emits more CO₂ to the
393 atmosphere, it may not sustainable in terms of climate impacts and sustainable economy at
394 global level. To examine this point, Life Cycle Assessment (LCA) can be a powerful tool.
395 LCA examines how each economic activity consumes material and energy, and releases
396 emissions. It evaluates the environmental performance of a system throughout its global
397 supply chain, by taking several impacts on human health and ecosystem quality
398 simultaneously into account (e.g. climate change, resource depletion, eutrophication, human

399 and ecotoxicity, etc.) (ISO 2006). In the case of the Thai fisheries, LCAs of different types of
400 fisheries were carried out, including data on local fishing gear, fuel consumption of each
401 fishery expedition (estimated by a GIS-track of each fishing boat), yields and their market
402 price. Preliminary analyses showed that materials for constructing boats, engines and fishery
403 gears of Thai fisheries mostly came from EU through global supply chains. Furthermore, the
404 emission of CO₂ and other wastes did not only differ among different fishery practice, but
405 also among different seasons of the year due to changes in fishery grounds with monsoon
406 conditions, which made assessment of environmental impact complex (Verones et al. under
407 review).

408 Use of combined ACC and LCA is thus found promising to evaluate whether good
409 practices developed by stakeholders and scientists are not only sustainable within local
410 community, but also environmentally less impacted in terms of global energy consumption
411 and emission of wastes (including CO₂). If the investigated practices are judged as
412 environmentally more sustainable, it will further enhance motivations of local community to
413 promote more sustainable local economic activities, considering conservation of biodiversity
414 and ecosystem services. In contrast, when LCA gives worse scores to current fishery
415 practices, it may give the community an opportunity to reevaluate their current practices
416 toward better decision making based on scientific data.

417

418 3. Linking local-scale ecosystem studies to decision making processes by multiple
419 stakeholders

420

421 As mentioned in the above section, good communication among scientists and stakeholders
422 based on precise scientific information is a key to achieve successful conservation of

423 biodiversity and sustainable use of ecosystem services. A bigger challenge comes when
424 different types of stakeholders co-exist who wish to use multiple ecosystem services in
425 different ways, and when they are in conflict over the use of these services. In the cases of
426 coastal ecosystems, for example, it is commonly observed that local commercial fishers who
427 use marine habitats for their yield (provisioning services) have conflicts with tourism sectors
428 who offer various types of leisure activities to holiday visitors such as angling, boating and
429 SCUBA diving (cultural services).

430 The integration of ecological studies and sociological studies with participation of
431 stakeholders can be a promising way to understand how the conflicts among stakeholders are
432 generated based on different uses of multiple ecosystem services. One of such integrated
433 studies has been recently initiated by linking ecosystem functions, ecosystem services and
434 their use by multiple stakeholders for eelgrass beds in Japan (Tajima et al. 2015). In their
435 approaches, they depicted the interrelationship among these components by listing up all the
436 different types of ecosystem functions and services from eelgrass beds, and linking these
437 categories with different types of stakeholders and their economic activities based on
438 intensive social surveys (interviewing and questionnaire surveys to local scientists and
439 different types of stakeholders) (Fig. 6, see Tajima et al. 2015 for the detailed methods).
440 Through the comparisons among different regions of Japan, they found that types of
441 stakeholders involved in the use of eelgrass beds, as well as the strength of their interactions
442 were different, depending on the regional variation in fisheries and other economic activities
443 (Tajima et al. 2015). Once the direction (either positive or negative) and the intensity of
444 interrelationships between ecosystem services and stakeholders are clarified, it will help
445 decision makers such as local governments and environmental committees to look for
446 solutions to reduce conflicts among stakeholders.

447 These approaches can be extended to the management of terrestrial and coastal
448 ecosystems within a watershed by multiple stakeholders (in our second perspective). One of
449 the most commonly observed cases is the conflict between farmers in the upper stream and
450 fishers in coastal areas within the same watershed where the changes in land use for
451 agriculture are claimed to be the causes for the reduction of marine resources through
452 deterioration of water quality via input from rivers (Diaz and Rosenberg 2009; Vitousek et al.
453 2009; Paerl et al. 2014). To look for the solution by agreements of farmers and fishers, first
454 requirement is to carry out quantitative assessment on the effects of land use changes on water
455 quality of rivers and coastal areas.

456 In the case of sediment and nutrient discharge to coral reefs, relevant case studies for
457 integrated environmental management based on a consideration for catchment-to-reef
458 continua was conducted in Okinawa of Japan (Yamano et al. 2015) and in the Great Barrier
459 Reef of Australia (Brodie et al. 2012; Thorburn et al., 2013; Waterhouse et al. 2016). In
460 Okinawa, a framework to integrate biophysics and socioeconomics, by setting a conservation
461 target and threshold, identifying the sources and processes, and examining cost-effectiveness
462 and management priorities was established and applied to Kume Island (Yamano et al., 2015).
463 The project resulted in initiating measures to prevent sediment discharge from sugarcane
464 fields with local government, NPO and farmers. In the GBR, the series of the studies showed
465 the Australian and Queensland governments responded to pollution concerns from watershed
466 runoff by developing an integrated plan to address this issue in 2003. Incentive-based
467 voluntary management initiatives were introduced in 2007, and a State regulatory approach
468 was implemented in 2009 (Brodie et al. 2012). However inadequate funding and reluctance to
469 enforce regulations led to limited progress in reducing loads of sediment and nutrients
470 discharged to the GBR (Brodie and Pearson 2016). The partial failure of this initiative showed

471 the necessity of strong enforcement of the regulatory regime in combination with voluntary
472 mechanisms for success.

473 The recent development of computer-intensive modelling of the dynamics both for
474 terrestrial and marine ecosystems can examine how the changes in land and sea uses and
475 farming and fishery practices can alter ecosystem services. Linking these terrestrial and
476 marine ecosystem models would be useful to evaluate quantitatively how the change in land
477 can alter the status of coastal ecosystems and the provisioning services such as fish and
478 aquaculture yield. The output from such combined models on the land-ocean connectivity will
479 be helpful to understand where the critical problems are located, and to establish agreements
480 among different types of stakeholders such as to set regulations on agriculture and fishery
481 options to retain sustainable ecosystem services.

482

483 4. Linking local-scale analyses of ecosystem processes to broad-scale analyses of ecosystem
484 patterns

485

486 A variety of tools, including remote sensing, GIS and simulation models are now available to
487 monitor, evaluate and forecast ecosystem functions and services at small spatial scales, such
488 as within a watershed as shown in the previous section. By establishing GIS-based ecological
489 databases, it is now possible to map the economic value of multiple ecosystem services
490 (Bateman et al. 2013). For example, methods of physical dimension measurement and
491 monetary evaluation were used to evaluate and map the spatial patterns of 11 ecosystem
492 services in the middle-lower Yangtze River watershed, China (Li et al. 2014). This research
493 confirms the irreplaceable role of wetlands in this watershed and identifies the core wetlands
494 and ecosystem services from a socio-economic perspective. The value of human-made

495 wetlands is 48% lower than that from natural wetlands, which reflects that conversion of
496 natural wetlands for aquaculture makes no sense from the sustainability perspective. In
497 another study conducted at Laizhou Bay, a very typical coastal ecosystem in China, Li et al.
498 (2016) analyzed the temporal and spatial changes in the value of 22 different types of
499 ecosystem services (6 provisioning services, 9 regulating services, 5 cultural services and 2
500 supporting services) and found that 43% decrease in ecosystem services value in this region
501 during 2000 to 2014 (Fig. 7). The ecosystem service values of water supply, waste treatment,
502 nursery service, genetic diversity, disturbance moderation, erosion prevention were lost
503 seriously due to the loss of coastal wetlands for the expansion of the construction land and
504 urban land. Land use change may seem economically profitable. However, due to the losing
505 of ecosystem services such as regulating or supporting services, the imbalance in ecosystem
506 services would impact the human well-being and socio-economic development. Policy
507 making should consider imbalance in ecosystem service, protect regional ecosystem services
508 function and maintain its stability.

509 Such GIS-based, fine-resolution analyses of ecosystem services can be applicable only
510 for limited areas where enough information of ecology and economy is available. When we
511 need to evaluate the ecosystem service values at broader-scale (e.g., along the whole coast of
512 Japan and China), we still need to rely on coarse-grain remote sensing data that can cover
513 wider area, and statistical data on economy and human population status summarized for each
514 local governmental unit. For example, using large-scale multi-resource data along the
515 mainland coasts of China (approximately 18,000 km) since the early 1940s, Hou et al. (2016a)
516 showed that due to the significant coastline artificialization mainly driven by sea reclamation
517 and coastal engineering, the remaining natural coastline accounts for less than one third in
518 2014. More thoroughly monitoring on recent changes of land use and wetland in coastal

519 China revealed that coastal land use and wetland changed acutely from 2000 to 2010,
520 resulting in the decrease of natural coastal wetland from 9956 km² to 3288 km², whereas the
521 increase of artificial wetland by 2592 km² (Hou et al. 2016b). Overall, the obtained results of
522 these studies showed drastic changes in the coastal zone of China which can be used to set the
523 baseline for the management purposes.

524 The integration of studies conducted at these two different spatial scales would be
525 worthwhile to extrapolate our findings to unstudied area where fine-resolution data are
526 insufficient, and to estimate the fine-scale processes at broader extent which is, in most cases,
527 practically impossible due to limitation in financial supports and manpower.

528 One of the prospect approaches for the integration of studies conducted at different
529 spatial scale have been proposed (e.g., Ghermandi and Nunes 2013), which should be carried
530 out by the following steps. First, select some representative sites covering in different
531 environmental and human socioeconomical conditions. Second, construct a database of
532 ecosystem service status in selected sites by a variety of methods, e.g., literature and report
533 surveys, field surveys of ecology and local human community. Third, conduct statistical
534 analyses to determine key relationships between ecosystem services and human activities
535 along some major environmental gradients. Fourth, extrapolate the focal ecosystem services
536 to broader-scale study area using the relationship obtained in the previous steps and the
537 broader scale spatial data built upon GIS. Finally, validate the extrapolated patterns by field
538 surveys in some unstudied sites, and feedback the results to improve the model prediction. By
539 repeating these processes, we can obtain clearer broad-scale, fine-resolution patterns of
540 biodiversity and ecosystem services with modest costs, which will offer more criteria for
541 decision making to enhance sustainable ecosystem service uses by multiple stakeholders and
542 decision-makers in various parts of each country.

543

544 **Concluding remarks: Major gaps and challenges**

545

546 Based on our project perspectives, we introduced here some ongoing studies by new
547 interdisciplinary and transdisciplinary collaborations toward conservation of biodiversity and
548 sustainable use of ecosystem services that are threatened by various stressors operating at
549 global and local scales. The integration of ecological and socioeconomic studies across
550 various spatial scales is promising to produce fruitful outputs which will be useful to solve
551 problems practitioners and stakeholders are facing. However, it is still unknown to what
552 extent our proposed approaches can be applicable to various cases in the world.

553 During the three workshops in 2015 and 2016, we found many gaps which can inhibit
554 to achieve our ultimate goals of collaboration. Firstly, biological and ecological data on
555 biodiversity and ecosystem services, as well as data on human utilization and awareness of
556 ecosystem services, are still lacking in many areas of Asia, especially in developing countries.
557 Take marine biodiversity data, for example, species distribution models predict the hotspot of
558 biodiversity in the coral triangle area (the Philippines, Indonesia and Papua New Guinea),
559 whereas actual data in global databases like OBIS and GBIF from these countries are far less
560 than those from other countries like Japan, Korea and China. More systematic approaches are
561 needed to be established to fill the biological and socioeconomic information gap in Asia

562 Secondly, there may be a gap in our knowledge of the ecological and social processes
563 among different types of ecosystems and habitats, e.g. among forests, plains, freshwater and
564 marine systems. Our projects mainly focused on coastal zones, which are influenced by both
565 terrestrial and marine ecosystem dynamics and where human is most densely populated in the
566 world. However, other types of habitats like inland forests, arid areas and offshore oceanic

567 islands will require adapted approaches. Basic integration, such as coupling of local data to
568 LCA studies and further upscaling to global impact studies via trade models work in principle
569 for all ecosystem types, however, the data required and the fine-tuning of the models needs to
570 be performed individually. Comparative approaches covering different types of ecosystems
571 are therefore worthwhile, in order to examine this further.

572 Thirdly, we still recognize gaps in types of stakeholders to be involved in the
573 transdisciplinary studies. So far, stakeholders in local communities have been well considered
574 such as the local fishers in Thailand of our ACC study. However, it is difficult to specify and
575 invite broader-scale stakeholders such as governors in provinces and countries, as well as
576 those responsible for international decision making. We already know that major stakeholders
577 who are responsible for the decline in global biodiversity are consumers in developed
578 countries (Lenzen et al. 2012). We still do not have any established methodologies to
579 effectively collaborate with such indirect and remote stakeholders in the transdisciplinary
580 science. Linking our sciences to the study on multigovernance, i.e., nested, hierarchical
581 structure of decision-making processes covering international, national and local politics,
582 would be a next step to fill up these gaps.

583 Finally and most importantly, there is still uncertainty in how we can link our
584 integrated approach to future scenario buildings. Our global economic analyses such as global
585 footprint analyses and LCA are very useful to elucidate the impacts of current human-induced
586 stresses on biodiversity and ecosystem services. However, by themselves, we cannot predict
587 any future changes. For the side of ecological study, future changes in biodiversity are
588 predicted for many types of organisms based on IPCC climate scenarios (Beaugrand et al.
589 2015; Molinos et al. 2016). Similarly, future scenarios on economy and governance have been
590 established and increasing (Hunt et al. 2012). These climate and economy scenarios can be

591 used jointly to predict future changes in biodiversity and ecosystem services although the
592 caution should be made about the difference in target times between most climate change
593 models (usually targeting 2100) and economy models (usually targeting 2030-50). As in
594 spatial-scale dependency of social-ecological systems discussed in our first perspective, target
595 temporal scales also vary among different subjects on environmental studies, which
596 integration should be investigated in future research.

597 To fill such gaps by developing more effective approaches, we can move forward to
598 establish new integration of solution-based sciences which are currently under development
599 by various scientific and policy-making organizations in the world. We are hoping that our
600 first attempts to link different fields of science and practitioners will lead to more intensive
601 collaborations that are not only useful but also stimulative and exciting.

602

603 **Acknowledgements**

604 We thank all the participants of three TSUNAGARI workshops for valuable discussions from
605 which this perspective paper was produced. We are also grateful to ILTER-EAP (Intertinal
606 Long-term Ecological Research Network, Eastern Asia and the Pacific regional network) to
607 consistent support throughout the research period. This research was funded by Belmont
608 Forum Collaborative Research Action on Scenarios of Biodiversity and Ecosystem Services
609 co-sponsored by agencies in Japan (JST), China (NSFC-BF/IGFA, No. 31461143032),
610 Australia and Norway (10444600). M.N was also supported by the Environment Research and
611 Technology Development Fund (S-15 Predicting and Assessing Natural Capital and
612 Ecosystem Services (PANCES)) of the Ministry of the Environment, Japan.

613

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897

898 **Figure captions**

899 **Fig. 1** TSUNAGARI perspective 1. Integration in social-ecological studies at various spatial
900 scales

901

902 **Fig. 2** TSUNAGARI perspective 2. Cross-ecosystem integration in both ecological and
903 socioeconomic studies

904

905 **Fig. 3** Areas of case studies on partial integration of the TSUNAGARI perspectives.

906 Horizontal and vertical axes showing the direction of integration presented in Fig. 1. Four
907 areas of integration are explained in each subsection of the main text.

908

909 **Fig. 4** Spatially explicit analysis of global biodiversity footprint showing global hotspots of
910 species threat linked to consumption in the European Union. Darker colors (red on land, and
911 blue to green in coastal sea) indicate areas of hotspots more threatened by EU consumption.
912 See Moran and Kanemoto (2017) for the details.

913

914 **Fig. 5** Diagram showing Area Capability Cycle (ACC) for the case of community-based set-
915 net fisheries in Thailand local fishery village. A new fishery practice (starting the set-net
916 fishery by the local community SEAFDC, indicated by the yellow box), which was more
917 effective in utilization of the resources than traditional fisheries, was established by the more
918 concern and care for ecosystem health by the local community (indicated by yellow thick
919 lines). The initial interaction between resources and local community was motivated and
920 driven by the hopes and prides of local community (indicated by a red box and black allows),
921 which brought positive feedbacks for the expansion of better practices, new skills and

922 industries (indicated by blue arrows and white boxes). Figure redrawn from Ishikawa et al.
923 (2015) with permission.

924

925 **Fig. 6** Diagram showing relationships among ecosystem functions (in round shape),
926 ecosystem services, and their use by different sectors of stakeholders for an eelgrass bed in
927 Japan. P: Provisioning services, R: regulating services, C: cultural services and S: Supporting
928 services. See text for more detailed information about how this diagram was made. Diagram
929 modified based on Tajima et al. (2015).

930

931 **Fig. 7** Changes in economic value of ecosystem services between 2000 and 2014 analyzed for
932 Laizhou Bay Coastal Zone, China. See Li et al. (2016) for the details.

933

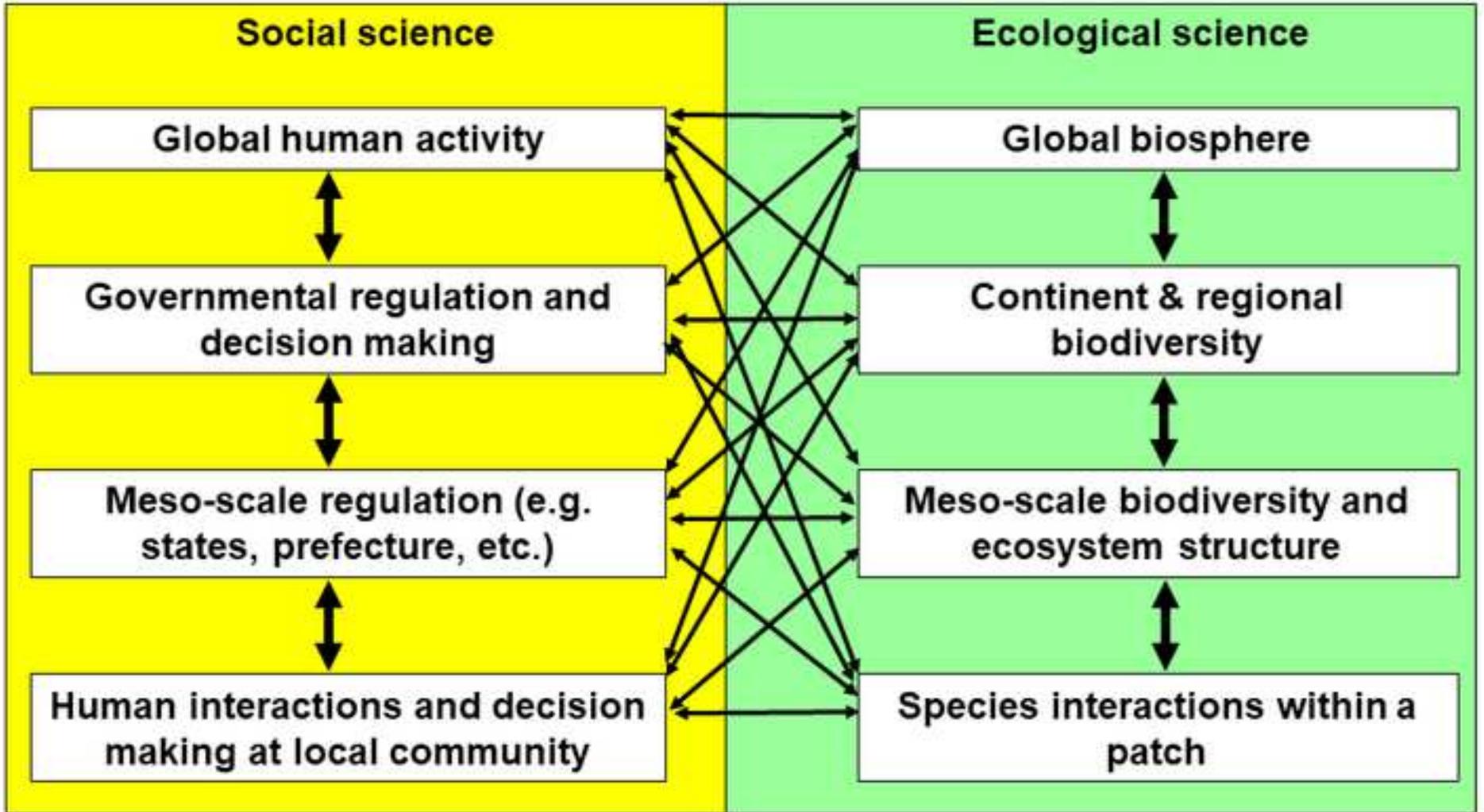


Fig. 1 (Nakaoka et al.)

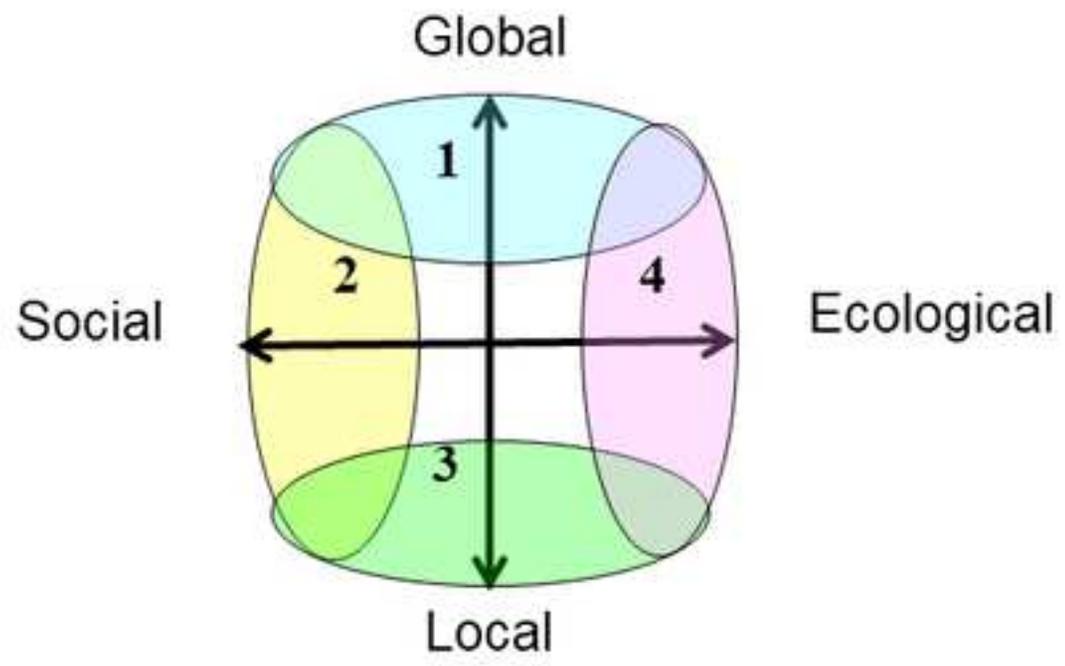


Fig. 2 (Nakaoka et al.)

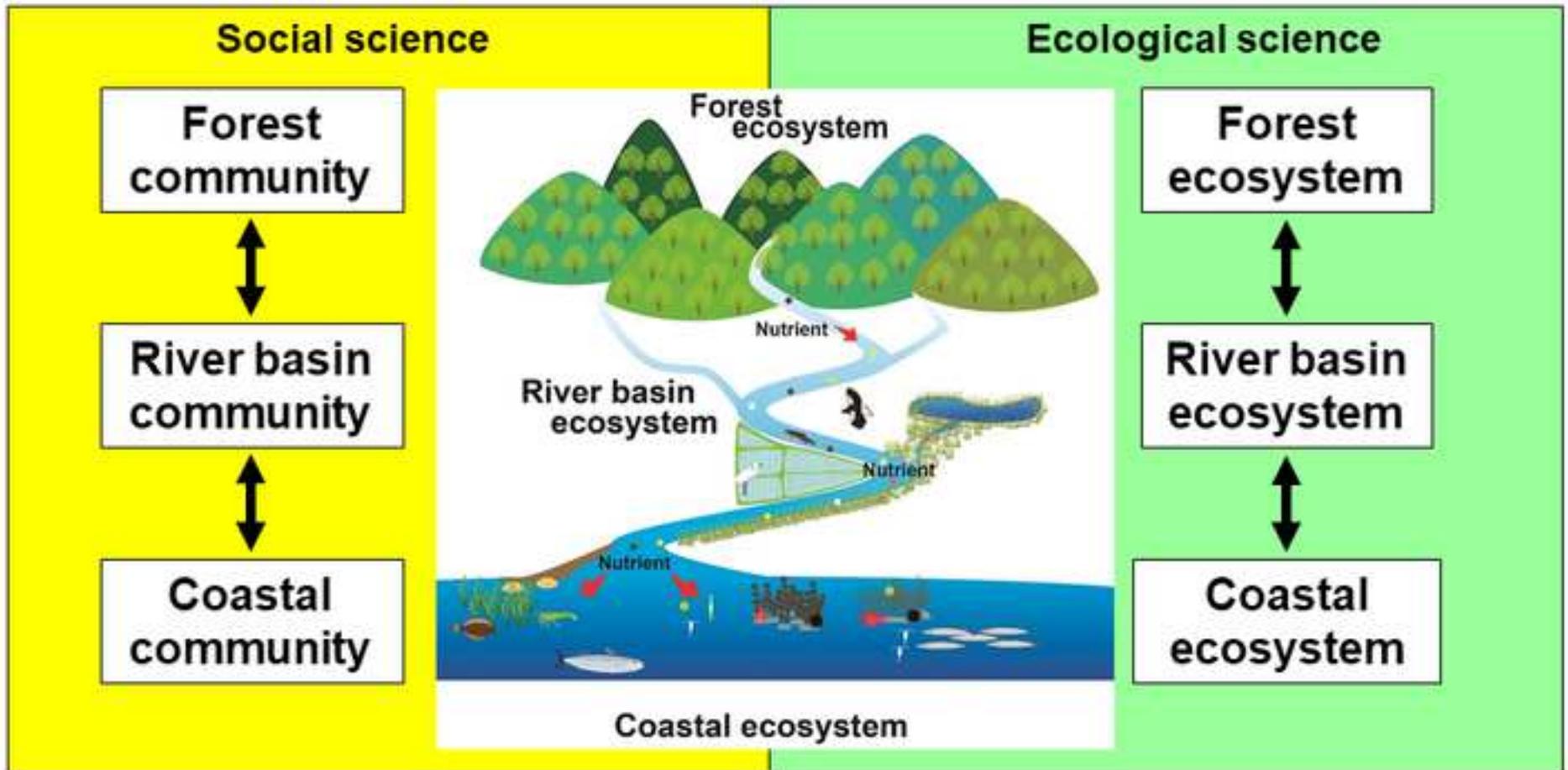


Fig. 3 (Nakaoka et al.)

Fig. 4

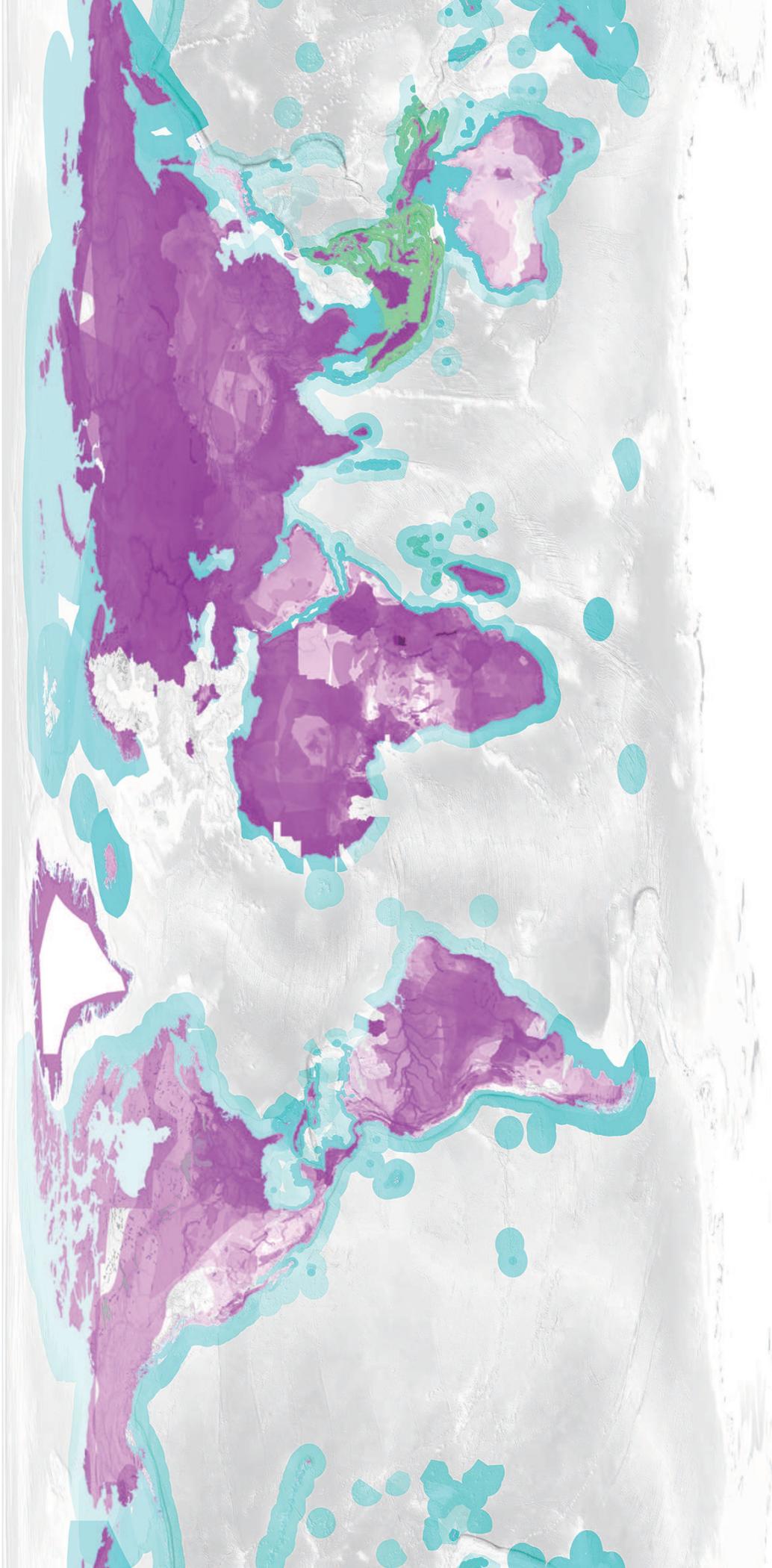




Fig. 5 (Nakaoka et al.)

Ecosystem functions and economic activities relating to sea grass bed

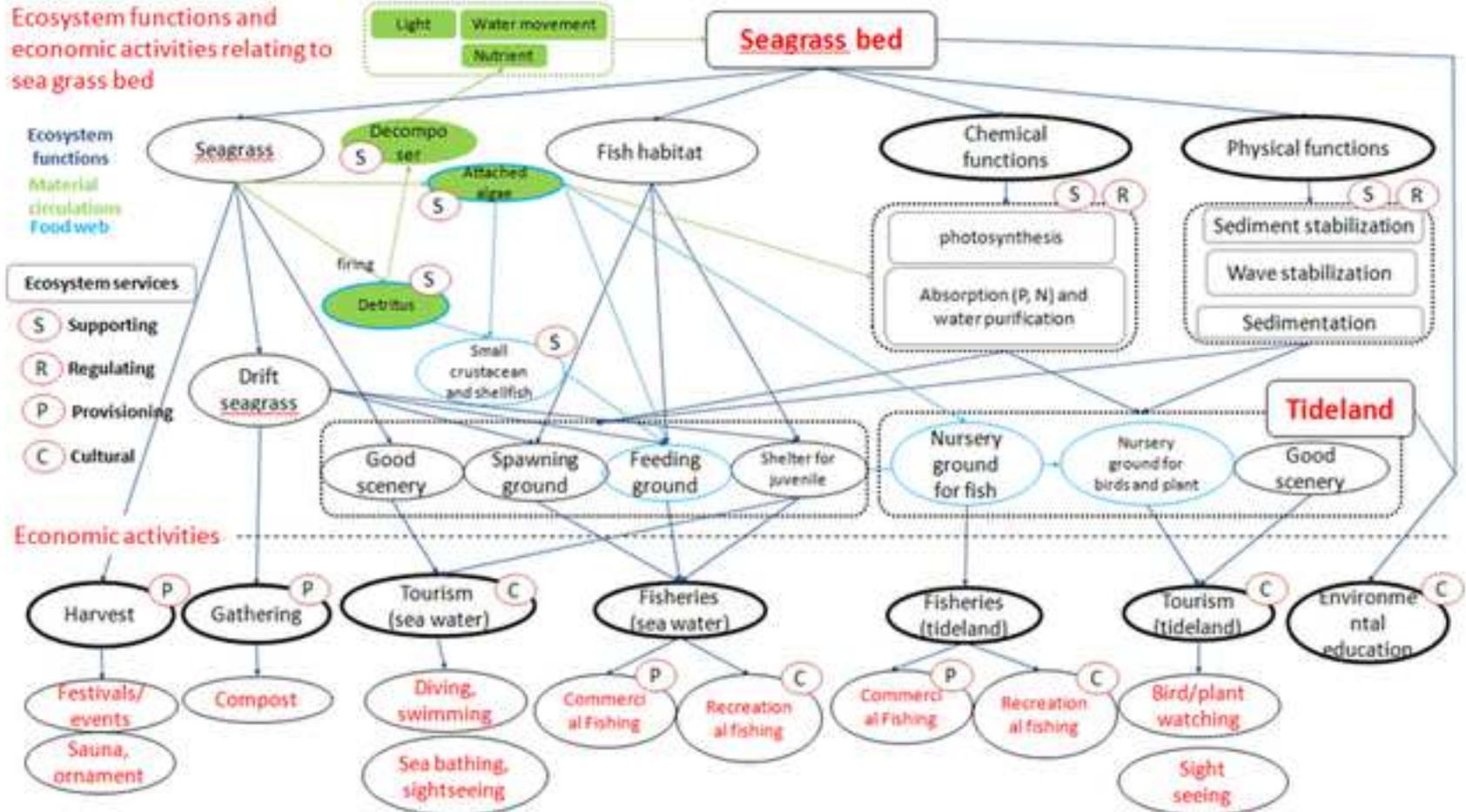


Fig. 6 (Nakaoka et al.)

Fig. 7

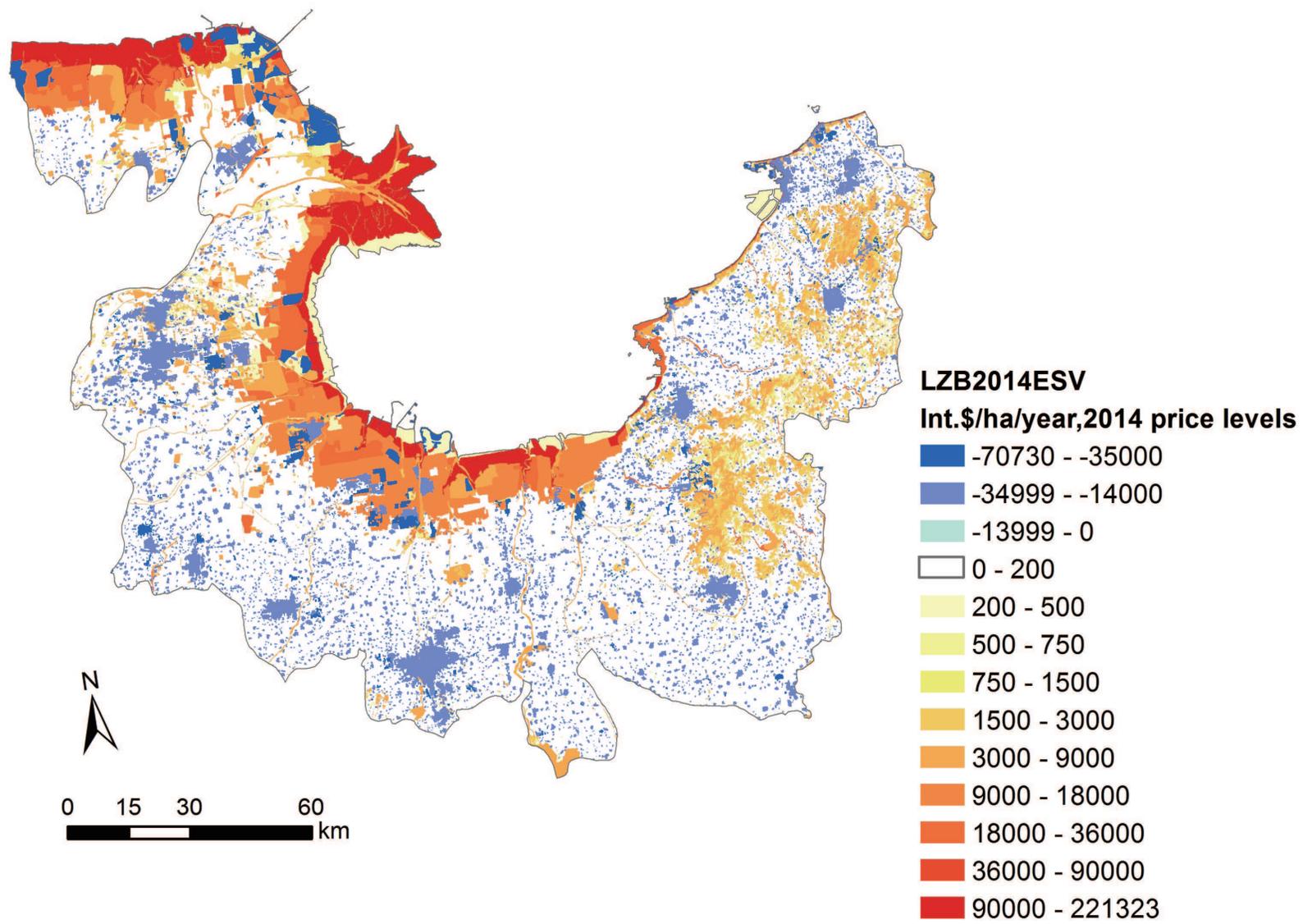


Fig. 7 (Nakaoka et al.)