Social Networks: Uncovering Social–Ecological (Mis)matches in Heterogeneous Marine Landscapes

Örjan Bodin and Beatrice I. Crona

Objectives

Ecological and socioeconomic processes often operate over different spatial and temporal scales. This can lead to increased risks of resource misuse and overexploitation if management is not well aligned with ecological processes operating in the landscape. One important way to ensure better alignment of social and ecological processes is through improved communication among relevant stakeholders operating at different scales and/or localities. Thus, understanding the structure and function of social networks is an important aspect of disentangling outcomes where different stakeholders come together to deal with natural resource dilemmas (Hum Ecol 34:573–592, 2006; Ecol Soc 11:18, 2006; Glob Environ Chang 19:366–374, 2009; Social networks and natural resource management: uncovering the social fabric of environmental governance, Cambridge, 2011). For example, active successful networking of a few key actors at the onset of a resource management initiative was important for building trust and buy-in from local farmers (Hum Ecol 34:573–592, 2006; Ecol Soc 11:18, 2006). Elsewhere, external connections were key to why some rural communities were more successful in initiating economic development; a few key individuals with enough education and skills had contacts with donors and agencies outside the village. These ties to external actors with resources were crucial in differentiating successful outcomes in otherwise very similar-seeming rural Indian communities (Active social capital. Tracing the roots of development and democracy, New York, 2002). In resource-dependent communities, particularly in the developing world, a lack of formal institutions or enforcement of regulations often means that resource users resort to informal social networks for coordinating resource use. To understand if and how social networks influence resource

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Ö. Bodin (✉) • B.I. Crona
Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden
e-mail: orjan.bodin@stockholmresilience.su.se

management, it is important to analyze both the patterns of communication but also how these patterns relate to key ecological processes in the landscape.

In this lab, students explore a social network of small-scale resource users targeting multiple species in a heterogeneous landscape. The study system is an artisanal fishery in a rural, coastal fishing community in East Africa. Students will learn to:

1. analyze important characteristics of a social network of small-scale fishers in an East African coastal village;
2. investigate the extent to which different personal characteristics (attributes) coincide with patterns of social relationships;
3. analyze how patterns of social relations among resource users can be tied to the geographic distribution of resource extraction;
4. discuss possible implications of their network results with regard to social and ecological (mis)matches; and
5. gain exposure to commonly used software within the field of social network analysis.

To accomplish the above objectives, this lab is divided into three exercises. In Exercises 1 and 2, students learn to analyze real social network data in conjunction with information on personal attributes of fishers, such as occupation, ethnicity, age, and education. In Exercise 3, these social networks are examined relative to maps of different fishing localities throughout the landscape. All network-related analyses will use NetDraw (available as a free trial version when downloading the software program Ucinet). Prior familiarity with graph theory is assumed; thus, Chap. 12 "Assessing Multi-scale Landscape Connectivity Using Network Analysis" in this book is a prerequisite for this lab. For those less familiar with small-scale fishing communities, Chap. 18 "Regime Shifts and Spatial Resilience in a Coral Reef Seascape" can also be a very helpful complement. All the necessary files (and links to software) are accessible from the book web site.

Introduction

The ways in which natural resources are extracted (and potentially misused) by societies is a result of multiple socioeconomic processes (e.g., economics, poverty, culture, and tradition) as well as structures (e.g., institutions that guide resource use, access to roads and markets). Another important factor affecting resource use and extraction is the amount and quality of information and knowledge available to resource users and other stakeholders. For example, a fisher unaware of the phenomenon of climate change and how it affects coral reefs cannot incorporate this consideration into his decisions about how much to fish or which gears to use to avoid further damaging the corals.

One can categorize the knowledge and information about the environment for resource extraction into two different but somewhat overlapping categories: (1) knowledge on how to maximize harvest while minimizing effort and (2) knowledge on how to extract resources in accordance with the natural limits posed by an eco-

system. The first category of knowledge, in a fishing context, would correspond to questions such as, "*Where are the fish?*," "*What gears should I use to catch the fish?*," and "*How do I deploy those gears in the most efficient way?*" The second category is more concerned with how extraction can be done without negatively affecting future use of the resource. In a fishing context, this could correspond to understanding fish stock regrowth limitations (e.g., maximum sustainable yields), how different fish stocks migrate between different localities during different life stages, and how the targeted fish species interact with or depend on other species and the physical environment. Knowledge of these processes reduces the likelihood of overexploitation. Yet it is important to acknowledge that even with good knowledge of a resource, overexploitation can and will often occur due to socioeconomic dilemmas like strong economic incentives and acute poverty (see Ostrom 1990). In such situations, the need to feed a hungry family will most often override any long-term concern for the biodiversity or resource sustainability (Barrett et al 2011). In conclusion, both types of knowledge are important in achieving sustainable natural resource use. Thus, ways to create a better understanding of different social structures and processes that create, maintain, and distribute information and knowledge in a natural resource management setting are important.

Informal Social Networks as a Conduit for Resource Users' Communication

What can a social network perspective add to our understanding of resource governance issues? To answer this, let us first briefly define what we mean by network analysis. A **network** can be thought of as a set of **nodes (actors)** and their **ties (relations)**. Network analysis is thus the study of social relations among a set of actors. A pair of actors that have relations can be said to share a social tie. Whereas mainstream social science is concerned with attributes of individual actors (e.g., income, age, sex), network analysis is concerned with attributes of pairs of individuals and the relations between them. These relations can be categorized into kinship (such as brother of, father of), social roles (boss of, friend of), affective relations (such as likes, dislikes), and actions (talks to, or attacks). This relational approach can add several important aspects to our understanding of resource management.

First, in any resource governance/management setting people collaborate and interact. Who is included or excluded from deliberation processes or decision-making can be important for management outcomes. Such patterns can be uncovered using a network approach. For example, in situations where users share resources, such as a fish stock, it is important that they are all willing and able to agree on and abide by common rules limiting resource extraction (Ostrom 1990, 2005). From a network perspective, one could argue this is more easily achieved when users are socially well connected, as opposed to in isolated groups without much communication. A well-connected group is more likely to agree on what rules need to be developed. Social connectivity could also make it easier to monitor fellow resource users to report or sanction rule-breakers.

Second, many resources constantly flow between people in any social setting, be it information, knowledge, capital, new ideas, etc. All these resources impact how people behave and choices they make and as such will influence resource management outcomes. However, the flow of resources between people is seldom homogenously distributed among all actors. Some people will share more resources with others, and some less. Some actors will have many ties, and thus access to many resources, while others will have few.

Imagine a class of high school students. A few students tend to be extra popular and have lots of friends. The vast majority of students may have a somewhat smaller number of friends, while often classes tend to have one or two students who do not socialize with anyone in the class. Translating this into network terms, we could say that the popular students would be hyperlinked, and the students without class friends would be considered isolates. Now imagine you arrived new to this class and wanted to quickly build up relations. By befriending a popular student, and getting invited to an upcoming party, your exposure to new people has increased very rapidly. If, on the other hand, you first become acquainted with one of the "isolated" students, you would most likely not be invited to the party. Within the context of the class, this student is unlikely to introduce you to any further friends. A central person, such as a popular student, has a certain amount of power to broker contacts, and depending on the social atmosphere in the class, acceptance or rejection by such a central student could greatly affect your future social network in the class. Actors playing such roles as hubs and "gatekeepers" exist in many networks and can be important in facilitating or impeding flow of resources throughout the network. In this lab, we are particularly interested in how the heterogeneous distribution of relations affects flow of information and knowledge among different actors in a network and how this could impact the two different types of knowledge outlined at the start.

By now, it should start to become apparent that mapping and analyzing the patterns of social relations among a set of resource users is useful in assessing and interpreting information flows and knowledge generating processes in a natural resource management context. In addition to the connections among actors, the characteristics (or attributes) of each actor are also important. This information can be vital in trying to understand why certain subgroups appear, if central actors tend to share some common feature or skill, and what this could mean for the study system.

Social Networks and Ecological Processes in a Rural Fishing Village in East Africa

With our short introduction to basic social network concepts in mind, let us now turn briefly to the type of networks in focus in this lab. Here, you will examine a social network of small-scale fishers who share information and knowledge about the state of the natural environment (the marine system) as well as extractive fishing practices. The fisher are all residents of a rural fishing village located on the Kenyan coast (see Crona and Bodin 2006 for a full description). The village has approximately 200 households and an estimated 1000 inhabitants. The surrounding area

has approximately 5 km^2 of mangroves with mudflats and seagrass meadows in the shallows and fringing coral reefs outside the lagoon. The use of resources in the village is centered on fishing, and in this lab a social network consisting of all 85 households (self-identified fishing households) is in focus. The study area represents a spatially heterogeneous landscape where many different species are harvested by many actors.

The high levels of heterogeneity and complexity in this system poses many management challenges, including: (a) many different groups of fishers are actively using the resource; (b) enforcement of regulations is weak due to limited governmental financial resources as well as difficulty in monitoring fishing occurring both day and night (making it difficult to predict when fishers will land their catch at the beach and thus assess their catch); (c) contrary to many developed-world industrial fisheries, this is a multispecies fishery, thus its management requires knowledge of not just one, but many different fish stocks (which are composed of species which also compete and prey upon each other). These challenges are similar to ones found in many terrestrial systems, such as small-scale agricultural landscapes or forests owned and managed by multiple different actors. Thus, the social network approach used in this lab is relevant to many other types of social–ecological landscapes.

Exercises

Exercise 1: Visualizing the Social Network

The dataset used in this lab consists of a set of social relations among small-scale fishers whose relations are used to exchange information and knowledge on issues related to the natural environment. Communication can occur in different ways. Some fishers work together on a boat may spend long hours at sea with ample time to share ideas and knowledge. Others may sit together after returning from the sea, discussing issues while mending their nets or enjoying a cup of tea at the local shop. However communication occurs, these types of informal social relations form the basis for understanding how knowledge and information flows through the community of fisher.

In this exercise, we will visually analyze the social network of these fishers. Each respondent is assumed to be the head of a fishing household, and thus no two fishers in the dataset are from the same household. The network data are in a file format used by the software program **Ucinet** (Borgatti et al. 2002) which is one of the most commonly used software packages for analyzing social networks. In this exercise, we use the helper application **NetDraw**, which accompanies Ucinet, to visually present the network in different ways.

Spring Embedding Network Visualization

There are many different techniques to visually present networks. A commonly used method is the "**spring embedding**" technique, which is a layout algorithm where each tie is treated as a spring which pulls actors towards each other (and the

absence of a tie acts as a repelling spring pushing actors apart). All attracting and repelling forces of the ties are considered together and the nodes (actors) arranged accordingly. Other visualization methods often build on this simple technique. In using the spring embedding technique, actors who are very central (with ties to many other actors) tend to be arranged in the middle, whereas less connected actors end up in the periphery of the plot. Subgroups (characterized by the fact that subgroup members have more ties among themselves than with others in the network) are arranged as clusters in the visualization of the network.

In the data for this lab, all ties are **binary** (present or not), **undirected** (we do not consider who in the pair had named the other, as long as one actor has named another we consider there to be a tie), and **unweighted** (we do not try to estimate tie strength, such as by asking actors how often they interact). Social network analysis often *does* include directed and weighted ties and use of such data will have implications for the interpretation of the results. While we do not delve any deeper into to this here, for more advanced analysis we refer readers to SNA text books such as Wasserman and Faust (1994). To get started, follow these steps:

- Start **NetDraw**.
- Open the network datafile "**Fisher.##h**" and choose the **spring embedding** layout technique in the menu **"Layout-Graph-Theoretic layout"**.
- Study the visual representations of the social network, answer, and/or reflect on the following questions.

Q1 To what extent is the community of fisher in contact with each other?
Q2 What is the relative connectivity of the fisher in the network? Why are some more central (i.e., more connected) than others?
Q3 Based on the patterns of relations observed here, to what degree do you think the community of fisher would able to come together and agree on common measures to regulate fish extraction?

Visualize Attributes of Fishers

Not all fishers in the village are the same as they typically fish at their particular favorite fishing grounds, specialize in different gears, and are embedded within different socioeconomic contexts. As a result, one might expect differences in knowledge and experiences among fishers. However, this does not mean that one fisher's knowledge is not helpful to another. In fact, the usefulness of others' experiences is particularly salient in the context of complex ecosystem dynamics. For example, accounting for multiple species interactions and migration might be crucial to successful fishing. Exchange of information and knowledge among different fishers would, at least in theory, provide for better opportunities to acquire a better and more holistic understanding of the underlying ecosystem.

NetDraw can be used to visually present the different attribute values of the fisher (the nodes). This is a powerful way to get a first impression of how and if

some attributes coincide with structural features of the network. In order to explore this further:

- Open the attribute datafile "**FisherAttributes.##h**" and make sure it is opened as an "**attribute**" datafile.
- Use NetDraw's drawing abilities to show the attributes in different colors, sizes, and shapes. Either use the two buttons on the "**toolkit**" menu (to define color and shape according to the attribute values), or use the menu item "**Properties-Nodes-Symbols.**"
- Consider the meaning of attributes in Table 1.
- Study the visual representations of the social network, answer, and/or reflect on the following questions:

Table 1 Description of fisher attributes

Attribute	Description	Values
Gear	What gear is the fisher's primarily fishing gear/method?	7—Middle man
		11—Gill net
		12—Spear gun
		13—Hand line
		14—Deep sea
		15—Seine net
Religion	What religion?	0—Unknown
		1—Islam
		2—Christianity
Lived in village	How long has the household been resident in the village?	0—Unknown
		1—0–5 years
		2—5–10 years
		3—10–20 years
		4—>20 years
Number of child	How many children in the household?	
House type	What type of roof of the household's house (an indication of how wealthy the household is)	0—Unknown
		1—Mud and thatch
		2—Cement and thatch
		3—Cement and iron plates
Age	How old is the fisher	
Tribe	To which tribe does the fisher belong	
Outside relative	How many close relatives outside the village does he/she have?	0—No relatives
		1—Only relatives that are local (i.e., close to the village)
		2—At least one relative from Tanzania

NOTE: The term "middleman" refers to the profession "fish monger" (and is not a gear type). Such individuals do not fish but are traders who buy fish at a landing site. They were included in the analysis as many have previously been active fisher and thus are knowledgeable and interact directly with the fisher on a daily basis

Q4 What attributes are shared among the most connected fisher?

Q5 How are fisher with similar attributes connected in the network? Do they cluster together or are they dispersed throughout the network?

Q6 Can you think of any implications—in terms of fishers' understanding of ecosystem dynamics—arising from either of these patterns (clustered vs. dispersed)?

Exercise 2: Analyze the Fisher Network

In this exercise, we will start to formally analyze some structural characteristics of the network. We will start looking for highly central individuals and then explore how different subgroups can be identified.

Identify Central Actors

In most networks, there will be a smaller number of actors who are significantly more connected than others (captured by their **degree centrality**, Fig. 1 Panel A). In a communication network of ecological knowledge, an actor with a high degree centrality could be influential since many people turn to him/her to access information about the natural environment. Another form of centrality is **betweenness centrality** which is the extent to which an actor indirectly connects other actors in the network. It indicates the potential of the actor to act as a channel for flow of information as well as other resources such as ideas and disease. Actors with high betweenness can be crucial in bringing different subgroups socially closer to each other by acting as bridges. The dark grey actors in Fig. 1 Panel B have higher betweenness centrality than the others in the subgroups. Some basic but fundamental analyses of node centrality can be done using NetDraw (and even more centrality analyses are available using Ucinet):

- In NetDraw, centrality measures can be found in the menu "**Analysis-Centrality measures**". Select both **degree** and **betweenness centrality**. NetDraw will then create new node attributes using the centrality scores for each node in the network.
- Use this new attribute data to draw the size of the nodes in accordance with their degree centrality scores. Use the menu item "**Properties-Nodes-Symbols-Size-Attribute based**" and select the **degree centrality** attribute.
- Other attributes can be simultaneously visualized using a different node color. For example, set each node's color based on its **gear type** attribute value.
- Repeat the above steps procedure for (Freeman's) **betweenness centrality** before reflecting on the questions below.

Q7 What attributes are shared among the most connected fisher (i.e., the ones with the highest degree centrality)?

Q8 Who are the fisher with the highest betweenness centrality?

Q9 Why do you think fisher with the highest degree and betweenness centrality could be important for the community's ability to manage their fish stocks?

a

b
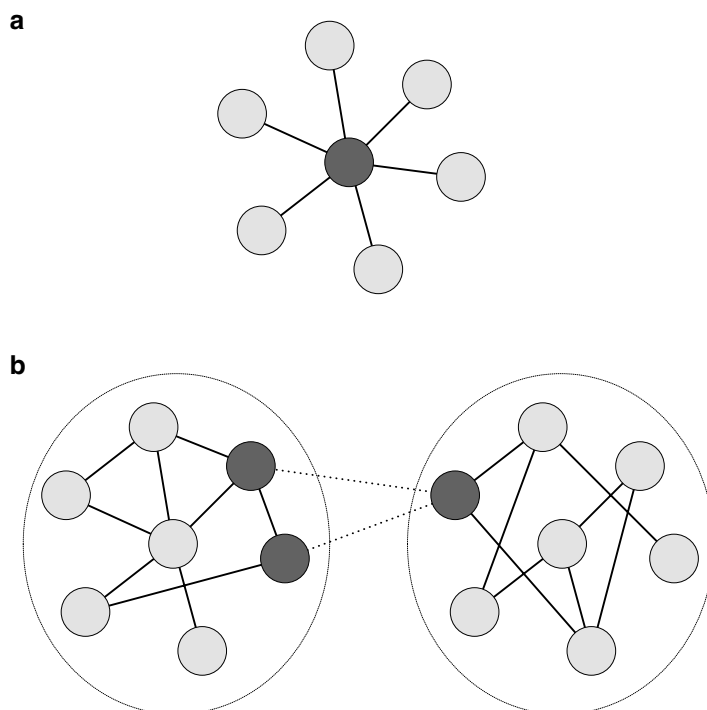
Fig. 1 Illustration of network characteristics. In *Panel A*, the network is highly centralized with an actor in the center with a higher degree centrality (i.e., higher number of links) than the others. In *Panel B*, the network is composed of two distinct subgroups (surrounded by circles). These subgroups are interconnected through links (*dotted lines*) connecting actors (in *dark grey*) who serve as bridges between the subgroups

Identify Subgroups

In many real-world social networks, actors tend to be clumped into subgroups (Fig. 1 Panel B). A few actors in subgroups may have ties to members of other subgroups thus connecting the network as a whole (Fig. 1 Panel B, dotted lines). Specific subgroups appear for different reasons related to the type of network under investigation. For example, in a friendship network they could represent cliques of close friends. In a network of fishers, it could represent a group of fishers using similar gears.

Numerous different analytical methods are available to identify different subgroups in networks. In this exercise, we will focus on **relationally** defined subgroups. Relationally defined subgroups are defined based on subgroup members being socially tied in similar ways and is in contrast to subgroups defined by some common **attribute** value (like being members of the same tribal group).

NetDraw can be used to identify subgroups (and even more methods are available using Ucinet). Here, we use a clustering algorithm which divides the network

into partitions consisting of different subgroups according to a **"Q" score** (aka **Modularity**, see Girvan and Newman 2002). Higher values of Q indicate a network composed of more distinguishable subgroups.

- Use the menu "**Analysis-Subgroups**". Select a high value for the maximum number of clusters (e.g., select 30).
- Visualize subgroup membership using different colors (as in the previous exercise).
- Choose the partition with the highest Q-value. Notice how the Q-value increases as the number of groups increase up to a certain point, and then typically declines when the number of groups further increase.
- Layout the network grouped by the subgroup membership attribute ("**Layout-Group by Attribute-Categorical Attribute**" menu item), and then try visualizing some other node attribute using different colors (such as type of gear).
- Consider if some of the attributes seem to coincide with the subgroup partitioning and the answer the following questions.

Q10 Can you find any distinguishable subgroups in the network?
Q11 What attributes distinguish these subgroups?
Q12 What do you think could be the cause of the patterns you've just observed? How could it affect governance of the resource?

Exercise 3: Compare Social Networks and Ecological Data

In this final exercise, the social network will be used to (qualitatively) analyze how the network and the ecological processes in the study area "match up," and explore possible consequences for natural resource governance. Our goal is to determine if there is a good "fit" between the flow of information among the fisher and ecological flows between different localities and species therein.

Analyze the Spatial Heterogeneity of the Seascape

The fish species targeted in the seascape represent a fairly heterogeneous mix of species at different trophic levels (grazers, benthivores, predators) which also exhibit different spatial distributions. Figure 2 illustrates the distribution of some major targeted species. Different types of fishing gear are typically used at different locations (Fig. 2), and Table 2 describes these fishing gears along with the major species targeted by each gear. Images and key characteristics of the major targeted species are also provided in Table 3 (from the book web site).

- Obtain a printout of Fig. 2 (or "seascape.jpg") as well as Table 3. Both are available from the book web site.
- Outline the spatial distribution of all the fish species *individually*, by encircling the areas where they are found.
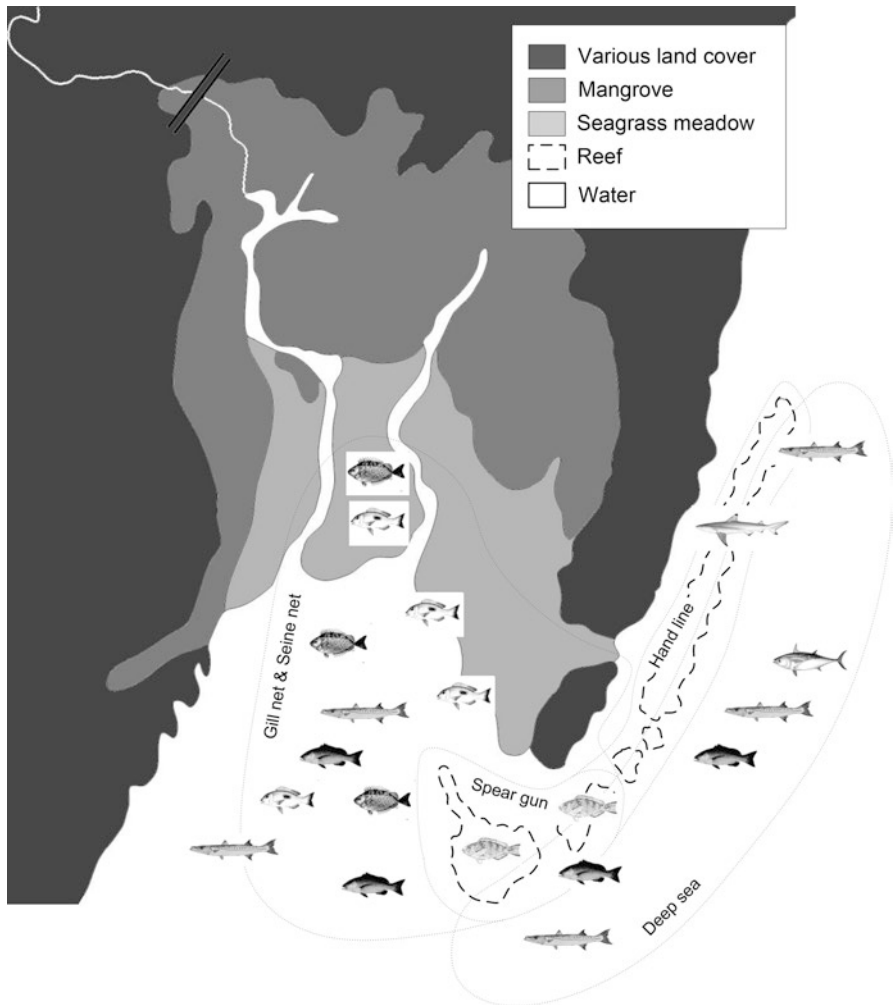
Fig. 2 Seascape map depicting fishing grounds according to type of fishing gear used. The localities used to catch targeted fish species are also identified. For printing, this image is available from the book web site as "**seascape.jpg**"

- Identify areas of overlap between these areas and the gear-defined fishing grounds (shown as dotted lines).
- Species being targeted by one or several types of fishing gears can be distinguished (also use information in Table 3).

Q13 Which species are targeted using multiple gears, and which species are targeted by only one specific gear?

Q14 What resource management implications might arise when different fisher using different gears target the same species?

Table 2 Description of fishing gear and some species targeted by these gears

Fishing gear	Description
Gill net	A net which is commonly used as a set net, i.e., it is not dragged actively in the water. Mesh size can vary.
	Main species targeted: *rabbitfish, emperor, snapper, barracuda*
Spear gun	A contraption (often home made) which, when deployed, releases a spear. Manly used for larger individuals of varying species, but primarily used on the reef.
	Main species targeted: *parrotfish, snapper*
Hand line	A line, usually with one hook, often dragged behind a canoe but also larger vessels. Hooks are often bated with smaller fish or squid depending on species targeted.
	Main species targeted: *barracuda, sharks, tuna-like species (e.g., kawkawa)*
Deep sea (purse seine)	A large net, usually of medium mesh size. It is deployed using two vessels. Divers in the water identify a school of fish and the vessels circle the school. Divers dive down and tie off (close) the bottom of the net which is then dragged onto the boat.
	Main species targeted: *mainly semi-pelagic species such as kawakawa, but also snappers, barracudas*
Seine net	Usually, a fairly small-meshed net of varying size. Can be very large. It is deployed out in the open water in the lagoon. A number of people proceed to haul the net onto the beach, while fishers in the water assist by making sure the net does not get caught on the bottom. The net tends to scrape the bottom substrate (much like a trawl) and catch species and individuals of all sizes, and is therefore considered a destructive gear.
	Main species targeted: *rabbitfish, sea grass parrotfish (not the same as S. ghobban found on the reef), as well as juveniles of snappers, barracudas, emperors, and semi-pelagics like kawakawa.*

Additional information and images of fish species can be found in Table 3 is an online resource only

Alignment of Social Networks and Ecological Processes

Next, we consider how well the social network and the heterogeneous seascape "match up." This is a group exercise so these questions should be discussed in small groups. Each group will then present their insights to the rest of the class. One initial way to consider how well social networks among resource users and ecological patterns/processes in land- and seascapes "match up" is to simply overlay and visualize them across the landscape. A compressed simplified version of the complete social network has been drawn atop the seascape (Fig. 3) showing subgroups based on gear type. (*NOTE:* if interested, see additional material from the book web site for how to do this). Previous research (Crona and Bodin 2006) has shown that fishing gear type often correlates with *relationally* defined subgroup of fishers (as you may also have discovered in the second part of Exercise 2). Because of this identified correlation, it makes sense to divide the network into gear-defined subgroups. In this new network, each node represents a gear type subgroup and any ties represent subgroup interaction.
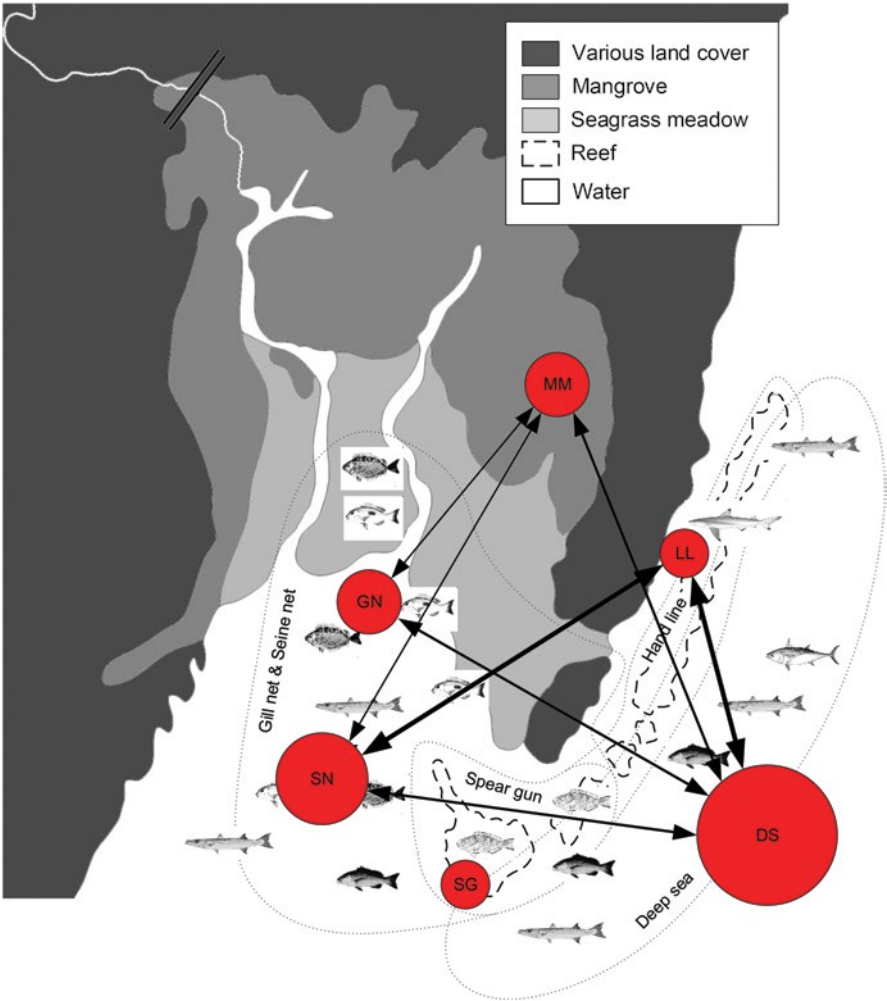
Fig. 3 The social network of fishers relative to the seascape and fishing grounds. Nodes correspond to subgroups defined by gear type used (and node size is proportional to size of subgroup). The figure helps depict the extent of communication among subgroups of fisher using different gears who may target different (and sometimes similar) fish species in different locales throughout the seascape. *DS* = Deep sea, *GN* = Gill net, *SN* = Seine net, *LL* = Land line, *SG* = Spear gun, *MM* = Middle men

Use Fig. 3, along with your answers and reflections from the first part of Exercise 3 to consider the concordance between different social and ecological processes and its implications:

Q15 Which gear-defined subgroups are communicating more than others, and with whom?

Q16 Are some fishers more (or less) decoupled from the other groups? Who would gain (or lose) most from increased knowledge and information exchange?

Q17 Consider the shared knowledge of fish species across different scales and localities. Which gear-defined groups are likely to have similar knowledge? Take into account subgroup communication as well as whether subgroups are targeting the same species.

Q18 Can you imagine any potential conflicts between different fishers targeting the same species (at similar or different localities)? Or between groups targeting interdependent species (e.g., predator and prey)?

Q19 To what extent might potential conflicts between subgroups of fishers (such as targeting the same species), coincide with social relations? What might the implications of such overlap (or lack thereof) be for conflict resolution?

Synthesis Questions

Let's take a step back and broaden our perspective and consider the following:

Q20 Consider the social and the ecological parts of the coupled social–ecological system (SES) we studied here—do they "match up" or align? Are there any apparent mismatches?

Q21 To what extent are the issues and themes of the lab specific to the context of small-scale fisheries vs. other heterogeneous social–ecological landscapes such as small-scale agricultural systems? Watershed management? Urban systems, forests, or parks and nature preserves? Choose another type of social–ecological landscape and explain.

Q22 Consider the shared knowledge of fish species operating over different scales and localities and think particularly about the kind of knowledge outlined in the introduction where focus was on understanding ecosystem processes. Which subgroup would you judge as having the most advanced understanding of ecosystem processes? Why?

Q23 Consider if some fishers increased their fishing efforts towards specific target species and specific localities. Can you identify any particularly vulnerable species and/or localities?

Conclusions

In this lab, we explored how the communication networks of resource users align with species distribution patterns to explore how patterns of social communication match ecological processes. We used a fishery example, but any human-dominated landscape could be analyzed in a similar fashion. The comparison of social networks and ecological processes was, in this lab, qualitative. More quantitative approaches are possible and examples include examples include (Janssen et al. 2006; Cumming et al. 2010; Johnson and Griffith 2010, Bodin and Tengö 2012; Guerrero et al. 2015, Treml et al. 2015, Bodin et al. 2014).

Resource extraction behavior and knowledge generation are inherently social processes affected by social embeddedness (Johannes 2002). How knowledge of ecological processes is distributed throughout community networks, and how this knowledge is translated into institutions that regulate extraction, are both impacted by social processes such as influence and diffusion, and are crucial for understanding spatial mismatches. The dilemma of the commons (Hardin 1968; Ostrom 1990), which can result in overexploitation and resource depletion, can be overcome through social collaboration and development of extractive norms (Ostrom 1990, 2005). A prerequisite for such collaboration is some basic communication and knowledge sharing to forge a collective understanding of the status of the system to be managed. Hence, communication between groups targeting similar species and operating in overlapping locations is of vital importance to avoid resource degradation and enhance the capacity for sustainable management.

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