Lessons on Connectivity and Conservation in Coral Reef Habitats: A Summary from the 11th International Coral Reef Symposium

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Introduction

Resources for implementing conservation activities are finite, and managers frequently struggle with finding the most cost-effective strategies for managing coral reefs and associated habitats. Traditionally, there has been a focus on the identification, categorization and protection of critical areas and natural events (e.g., barrier reefs, mangrove habitat of juvenile fish and invertebrates, and spawning aggregations). While this is necessary, without understanding the physical and biological interactions and connections among these areas we can only gain a glimpse of the biological reality. Knowledge of these interactions reveals the system's true richness and complexity, which enables managers to be more effective in prioritizing critical areas for protection.

To better understand how areas associated around coral reefs are connected, over 200 scientists presented their insights during a special session on reef connectivity at the 11th International Coral Reef Symposium (ICRS) in Florida, July 2008 (go to http://www.nova.edu/ncri/11icrs/ms14_orals.html to view abstracts). Following is a summary of the key findings from over 60 presentations that have particular relevance to conservation and management of coral reefs. These are centered around four lessons:

- Larval recruitment occurs on a smaller scale than previously thought.
- Inter-archipelagic connectivity is limited.
- Oceanographic models can help managers assess reserve design options.
- Ecological monitoring and genetic connectivity studies need to join forces to effectively characterize population dynamics.

These findings highlight the importance of focusing conservation efforts at a local scale.

Larval recruitment occurs on a smaller scale than previously thought.

A decade ago it was argued that reef fish larvae were too small or too weak to make headway against powerful oceanic currents. However, data collected using a wide variety of research methods are suggesting that reef fish larvae are not only capable of moving in a meaningful fashion, but they also possess the brain function to identify potential settlement areas. Consequently, we are finding that many more reef fish larvae are settling "closer to home" and therefore, reefs are connected over much smaller spatial scales than previously thought.

A good example of this mutli-disciplinary research has been undertaken in Kimbe Bay, Papau New Guinea (PNG). Using a variety of techniques, it was found that approximately one-third to one-half of the reef fish settling in this bay were returning to the same neighborhood (a 0.3-km^2 reef) in which their parents had settled. This independent confirmation suggests that these fish larvae have a powerful ability to return to their own reef—a finding that has been demonstrated empirically through mark and recapture studies in the same bay (Almany *et al.*, 2007; Jones *et al.*, 2005). Similar results were reported in numerous ICRS presentations, including those from Hawaii, the Bahamas, and St. Croix.

Additionally, innovative research projects have shown that reef fish larvae are actually able to discriminate reefs by smell and preferentially choose water from the reefs on which they were hatched (Gerlach *et al.*, 2007 Gardiner *et al.,* in prep), thus demonstrating a potential mechanism for this homing behavior. These studies, along with others (Jones *et al.*, 1999; Swearer *et al.*, 1999) support the key finding **that many coral reef fishes are settling close to home. This indicates that reef fish are demographically dependent on populations up to 10s of kilometers away, and that there is a high degree of self-recruitment in these populations. (See abstracts by Atema *et al.*, Christie *et al.*, Figueira, Gardner and Jones, Hamilton and Warner, Jones *et al.*, Planes *et al.*, Starger *et al.*, Thorrold *et al.*, and Tupper** at http://www.nova.edu/ncri/11icrs/ms14_orals.html).

Inter-archipelagic connectivity is limited.

A number of the presentations at the conference highlighted that populations of coral reef organisms in archipelagos have a high degree of isolation. For instance Drew *et al.,* (2008) found that the Fijian populations for five species of fish were genetically distinct from populations in the rest of Melanesia, showing that they are evolving independently. Similar patterns of archipelagic isolation have been found in snails (Meyer *et al.*, 2005) and in coral (Palumbi *et al., in prep*). These genetic findings have been echoed by an investigation of connectivity using mathematical modeling of oceanic currents which shows a high degree of isolation between several Pacific archipelagos (Treml *et al.*, 2008).

These findings mean that in many island nations, reef populations are functionally independent, despite many of these species being broadly distributed. Because of this functional independence, if localized disasters strike one island group (such as an oil spill, or bleaching event), it is unlikely that species will be replenished from sources outside that archipelago. From a management perspective this finding highlights that **what may seem to be a local extirpation may in fact represent a global extinction of a unique genetic lineage, and that there is a critical need to protect this endemism in archipelagos. (See abstracts by Colin, Drew and Barber, Lasker *et al.*, Palumbi and Ladner, Toonen *et al.*, Treml and Halpin, and Underwood *et al.*,** at http://www.nova.edu/ncri/11icrs/ms14_orals.html).

Oceanographic models can help managers assess reserve design options.

Recent advances in our ability to generate data, coupled with increases in computational power to analyze those data, have brought about a renaissance in modeling the marine environment. It is now possible to use two different types of models (oceanographic and decision-support) to greatly facilitate marine reserve design. Presentations on the first kind of model, largely oceanographic in nature, showed how one can take basic life-history information and couple that with oceanographic information to make predictions as to where areas of high recruitment may occur (Cowen *et al.*, 2006; Paris *et al.*, 2007; Kool *in prep*), or areas where predator prey dynamics may be influenced by oceanographic conditions (Warner *et al., in prep*). Given that information, managers can create a list of candidate sites that are likely to be linked via larval exchange.

With the second type of model, managers can take this first list of candidate sites and identify combinations of candidate sites. This can be done using a variety of freely available software packages such as MARXAN (http://www.uq.edu.au/marxan/). These programs sequentially add candidate sites until a number of pre-defined conditions (such as 20% habitat coverage, all habitat types represented, minimized user conflicts, etc.) are met with lowest possible "cost," and biological patterns of connectivity can be taken into account.

With both of these tools it is important to recognize that the quality of any model is dependent on the quality of the data on which the model is built. For oceanographic models this means that it is important to have small-scale research projects (such as those in Kimbe Bay, PNG, *see previous page*) to validate large-scale model predictions. For reserve design models, it is important to recognize that there are often many equally optimal solutions and that the software will produce options that will serve as the starting point for further critical discussions.

As several presenters such as Berger and Possingham noted, the earlier the stakeholders are brought into the conversation the less contentious the ultimate reserve selection process will be (Fernandes *et al.*, 2005). For example, by identifying key fishing areas ahead of time, these data can be used by reserve selection software to develop a reserve design that would seek to maximize conservation benefits within a context of recognizing the fishing community's needs. **Together these models can provide insight into large-scale population dynamics and can be used to optimally allocate finite conservation resources while minimizing conflict. (See abstracts by Beger and Possingham, Cowen *et al.*, Galindo *et al.*, Irisson *et al.*, Kool *et al.*, Foster *et al.*, Paris and Aldana Aranida, Paris and Baums, and Villanoy *et al.*,** at http://www.nova.edu/ncri/11icrs/ms14_orals.html).

Monitoring is a critical component to characterizing population dynamics.

While the number of research studies on reef connectivity have increased, many of these have been limited to small-scales by the extensive costs necessary to mount large-scale, multi-year studies. Small-scale studies provide useful glimpses of how nature behaves at a particular place and time; however, the leap from the specific finding to the general rule needs to be made with caution. For example, many reef fish are recruited in pulses or waves; a study on coral reef fish that focuses only on one field season will just be a snapshot of a particular place at a particular time. When sampling over multiple years, drastically different results can be obtained from year to year. Because of this potential for variability, scientists and managers should partner to implement a repeated schedule of surveys (i.e. long-term monitoring) throughout the years (Gerlach *et al., in prep*).

Surveys should include physical (water temp, clarity, etc.), ecological (species identification) and potentially genetic (15–20 individuals of a species) parameters. If facilities to process the genetic samples are not available, establishing partnerships with competent labs could provide a great opportunity for collaborative research. In this way managers collect the data as part of their standard surveys and the partner lab conducts the analysis on an annual basis. The data provided by the surveys will contain valuable information for establishing the long-term trends necessary to determine the various larval sources, as well as how changes in environmental conditions can impact recruitment. **This multi-disciplinary sampling will create robust and defensible conclusions about the larval dynamics of the particular managed areas and provide the basis for adaptive management decision-making. (See abstracts by Gerlach *et al.*, Atema *et al.* and Hogan *et al.*,** at http://www.nova.edu/ncri/11icrs/ms14_orals.html).

Conclusion

The science of coral reef habitat connectivity is growing rapidly. Improvements in technology and an increasingly multi-disciplinary approach to research are producing a wide variety of exciting projects — with the ultimate goal of understanding how various reefs are connected and, by extension, how we can best apply limited conservation resources to garner the greatest ecological benefit.

We have seen that the scale of population connectivity is much smaller than we expected, often occurring at the scales of tens of kilometers, and that locally produced larvae may contribute a substantial proportion to the larval supply. While there are still research gaps, particularly regarding connectivity between the 10–100s of kilometers scale, we have found that the development of large data-rich models can provide a realistic overview of the ways in which populations can be connected. However, models are only as valid as the data that enter them, and they need to be validated with small-scale, resource-intensive research projects.

There has also been the realization that islands may harbor previously unknown levels of endemism (genetic uniqueness) and there is a need to increase the number of species sampled across archipelagos and to maintain long-term genetic monitoring. Both are necessary if the goal is to conduct sustainable management of the living marine resources. One of the unifying themes throughout all of these presentations was the critical need for effective management at the local scale. While much effort has been put into the development of broad-scale conservation measures, the application of those theories relies on the efforts of local managers, for they represent the front line of successful marine resource conservation.

Works Cited

Almany GR, Berumen ML, Thorrold SR, Planes S, Jones GP (2007) Local replenishment of coral reef fish populations in a marine reserve. *Science* **316**, 742–744.

Cowen RK, Paris CB, Srinivasan A (2006) Scaling of connectivity in marine populations. *Science* **311**, 522–525.

Drew JA, Allen GR, Kaufman L, Barber P (2008) Regional color and genetic Differences demonstrate endemism in five putatively cosmopolitan reef fishes *Conservation Biology* **22**, 965–975.

Fernandes L, Day J, Lewis A*, et al.* (2005) Establishing representative no-take areas in the Great Barrier Reef: large-scale implementation of theory of marine protected Areas. *Conservation Biology* **19**, 1733–1744.

Gerlach G, Atema J, Kingsford MJ, Black KP, Miller-Sims V (2007) Smelling home can prevent dispersal of reef fish larvae. *Proceedings of the National Academy of Science* **104**, 858–863.

Jones GP, Millcich MJ, Emsile J, Lunow C (1999) Self-recruitment in a coral reef fish population. *Nature* **402**, 802–804.

Jones GP, Planes S, Thorrold SR (2005) Coral reef fish larvae settle close to home. *Current Biology* **15**, 1314–1318.

Meyer CP, Geller JB, Paulay G (2005) Fine scale endemism on coral reefs: archipelagic differentiation in Turbinid gastropods. *Evolution* **59**, 113–125.

Paris CB, Chérubin LM, Cowen RK (2007) Surfing, spinning, or diving from reef to reef: effects on population connectivity. *Marine Ecology Progress Series* **347**, 285–300.

Swearer SE, Caselel JE, Lea DE, Warner RR (1999) Larval retention and recruitment in an island population of a coral-reef fish. *Nature* **402**, 799–802.

Treml EA, Halpin PN, Urban DL, Pratson LF (2008) Modeling population connectivity by ocean currents, a graph-theoretic approach for marine conservation. *Landscape Ecology* **23**, 19–36.

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