Title
Reef Fish Monitoring Techniques: Assessing the Possibility of Producing Comparable Data through a Standardized Method

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Reef Fish Monitoring Techniques:
Assessing the Possibility of Producing Comparable Data through a Standardized Method

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Introduction:

It is widely documented that reef fish populations are declining on a global scale as a result of habitat loss and degradation, pollution, over fishing, and lack of management and enforcement (Dulvy et al. 2004, Knowlton and Jackson 2008, Munday et al. 2008, Pandolfi et al. 2003) Tissot 2005). In order to understand the threats that impact near shore habitats quantitative techniques must be developed to assess and monitor reef fish assemblages (Bell et al 1985). Efforts to document fish assemblages are being conducted around the globe to document the current state of reefs and identify the anthropogenic factors that affect reef health. Most of the methods used to assess assemblages of fishes are fisheries independent and rely on divers to make visual assessments which results in minimal impacts to the ecosystem. These fisheries independent methods are rather simple to employ and have been used to estimate abundance and biomass of fishes and understand the ecological effects of fisheries exploitation and environmental disturbance on near shore ecosystems (DeMartini et al. 2008, Sandin et al. 2008, Stallings 2009).

Numerous academic, government, and non-government institutions incorporate a variety of visual census methods into their monitoring programs. Methods vary depending on multiple factors including the research question being asked, the species' ecology, spatial distribution of species of interest, environment being studied, and the suitability of the method to the research program. As such, the results obtained from each method are oftentimes incomparable due to the spatial and temporal scales adopted by each method. Though a wide variety of methods are currently being used, three methods seem to be the most prevalent within the research community to survey reef fishes: the belt transect, stationary point count, and timed visual assessment methods.

The belt transect method was first developed by Vernon Brock in 1954. This method consists of a team of divers swimming along a transect and tallying the fishes observed in a predetermined swath (Brock 1954). The most common transect length is usually 25m or 50m. As the divers swim along the transect all fishes that are observed within the predetermined transect swath (usually between 2-5m) are tallied and their size estimated. Transects typically run parallel to shore and follow a consistant depth and habitat type. The speed at which the dive team moves along the transect is important for estimating the abundance of fishes with the goal being to take a snap shot of the fish assemblage along the transect. If the dive team swims too fast benthic dwelling or slow moving species may be overlooked and result in an underestimate of the population. Alternatively, if the dive team swims too slowly they can overestimate large-bodied or mobile species that may enter the diver's field of view along the transect (Samoilys and Carlos 2000).

The Stationary Point Count method (SPC) was first developed by James Bohnsack in 1985. Stationary Point Counts involve a diver recording fishes within a predefined cylinder area along the reef. The method only requires one diver. The diver remains stationary while counting all the fishes from the bottom to the top of the water column in an imaginary cylinder for a set amount of time. The radius of the cylinder is set as a constant for the project (usually between 5 and 10 meters depending on visibility and targeted fish species). Larger, more mobile fishes are counted first then the more sedentary species are counted (Samoilys and Carlos 2000).

The timed visual assessments use time as the constant, similar to the SPC. These timed assessments most commonly focus on larger species of fishes (usually greater than 20 centimeters) that are usually targeted by fishers for consumption while small-bodied species are usually ignored. Timed visual assessments are typically used to cover a large amount of reef area. Divers take a compass heading and swim in a constant direction and depth for a set amount of time. To cover large areas of reef the divers usually swim at a quicker pace or use tools such as tow boards or underwater propulsion devices to maximize reef coverage (Kenyon et al 2006).

Comparisons of the belt transect method and the stationary point count method have found that there is no significant difference in measuring fish densities between the two methods (Samoilys and Carlos 2000). Since there seems to be no advantages to either method, choosing the appropriate survey technique is usually due to the research question being asked, researchers preference, experience, training, and personal bias (Samoilys and Carlos 2000).

Although studies have shown no significant differences in the measurements in fish densities between the SPC and belt method, each survey method introduces its own inherent biases. These biases relate to the difference each method has on how well it targets and identifies certain species of fishes, or size of fishes. Survey techniques that survey swaths of reef greater than one meter have been shown to decrease the detection of smaller, cryptic species (Bozec et. al. 2011). Biases also relate to the observation area or area of reef that is being surveyed. Certain survey methodologies do better than others at capturing an instantaneous picture or a snapshot of the reef at the time of the survey. If a survey technique takes longer than others to carry out then the possibility of fish moving into the survey site could increase the recorded biomass and not give as much of an accurate snapshot of the reef (Bozec et. al. 2011). Another bias is how the fish react to the presence of the diver. The way the diver moves during the survey or the speed at which the surveyor swims could cause an attraction or avoidance behavior in certain species of fishes that could alter the biomass that is recorded (Bozec et al 2011). All of these factors, differences, and biases in the techniques cause the data that are produced to not be easily comparable between one another.

In order to ensure that survey efforts are as effective as possible at showing how factors are impacting reef fish assemblages across regions inter-comparability between methods is very important. Using methods that produce comparable data would allow managers to have access to complete information that could help them to make the most educated and informed management decisions possible.

Purpose of Project:

The purpose of this project was not to develop or even necessarily recommend a standard or best method that is to be used across all regions. The purpose of this research was to provide the research community with a holistic view of the work that was being done around the world. The issue and discussion involving standardization of survey methodologies has been ongoing for some time now. This project was to gather information from the research community as to their thoughts and comments on the topic of standardizing methodologies. The project was also aimed to act as a catalyst to build momentum and generate discussion among the research community towards a solution to this issue.

Methods and Materials:

The data that were collected to answer the questions of this project were mainly collected through the development and dissemination of an online survey. An online survey software program, Qualtrics™, was used to provide the template and structure for the survey. The data that were collected during the survey were also relayed and housed in a personal Qualtrics account. There were a total of twenty questions asked in the survey. The survey was split into two sections. The first section focused on collecting data on the methods that were being used to assess reef fish assemblages and diversity. Questions included:

1. What is the general research question that reef fish surveys help to answer in your research?
2. Where is this research involving fish surveys currently being conducted?
3. What is the purpose of the data that you are collecting?
4. What survey method is being used in your research?
5. How did you choose the methods for this project?
6. How were these methods developed?
7. If the methods were adopted or modified from another institution, what institution or organization were the methods adopted from?
8. How often are your fish surveys conducted?
9. How long have you been conducting your surveys?
10. How long do you plan to continue this research project?

The second section of the survey aimed to collect the research community's thoughts and feelings on the issue of developing and implementing a standardized fish surveying method for near shore fishes. Questions included:

1. Do you think it is valuable to have a single method across regions?
2. To what extent are you willing to modify your current methodology to produce a standardized reef fish surveying method?
3. What factors affect your willingness to modify your methods to a standardized methodology?
4. Why do you believe there has not been one standardized fish survey method adopted across all regions?

The final few questions collected demographic information on the respondent's role in the project, their highest level of education and where they earned their degree from, age, and gender.

The survey was linked to an email that was sent to researchers around the world. An initial list of researchers was gathered from existing colleagues and contacts. NOAA's CORAL List and the American Academy of Underwater Sciences directory were both used as forums to reach a large part of the research community. The email asked the recipients to further forward the email with the survey link on to their colleagues. As results started to be analyzed a map was generated that highlighted where responses had been gathered thus far. The map was sent back out to the original email list and forums in hopes of generating incentive to gather information from areas that had not yet responded to the survey. A more regionally based search for researchers in this field was conducted internally to try to gather information from regions that had not gotten a lot of responses.

Pearson's Chi-squared test with simulated p-value (based on 9999 replicates). The Yates' correction for continuity was conducted for tests that had only one degree of freedom. These Chi square tests were run through the program "R" to test the following null hypotheses:

- Method used is independent of study location.
- Method used is independent of researcher location
- Method used is independent of study duration.
- Method used is independent of research question.
- Willingness to modify method to a standardized method is independent of study duration.
- Willingness to modify method to a standardized method is independent of motivation for study.
- Willingness to modify method to a standardized method is independent of the question being asked.

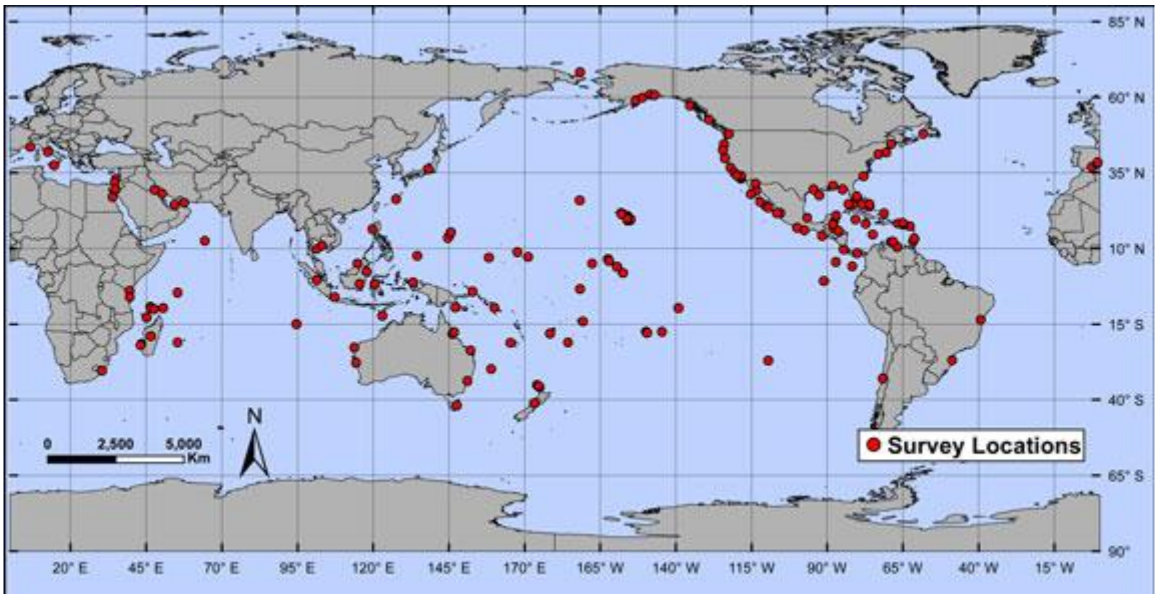
In hopes of getting the information from the study back to the research community as effectively as possible a website was developed to provide a summary of the survey results. The website listed and described all of the fish survey methods that were recorded during the survey, provided a map that displayed where these methods were being used, and showed comparisons between the research questions being asked and the methods that were being used to answer those questions. The website also presented the thoughts and comments from researchers on why a standardized method had not been developed, and highlighted the reasons why researchers thought a standardized method was or was not important. The site also includes anonymous quotes from researchers that were collected during the study in hopes of conveying personal insights and feelings on both sides of the issue of standardizing survey methodologies.

Results:

Responses:

It is estimated that the email with the survey link attached reached at least 4000 individuals in the research community. It is understood that some of these email recipients were not in the field of assessing reef fish assemblages but may have had expertise in other areas of marine science. These individuals would not have an interest or incentive to open the email or conduct the survey. 417 of those researchers who received the survey actually opened the link and started the survey. 180 individuals submitted completed surveys. The methods that were recorded represented 191 countries, islands, regions, states, and communities (see Appendix 1).

The figure below is a map that shows the spatial distribution of the responses. Each red dot indicates a response from an individual who is doing work in that area.



Research Questions:

There were a variety of research questions that were recorded during this study. Every question was related to assessing reef fish assemblages but many focused on different impacts. The questions could be could be condensed into 15 topics:

1. Measure biodiversity and abundance
2. Spatial and temporal variation
3. Assess efficacy of marine management
4. Anthropogenic impacts on fish stocks
5. Overall reef health and ecosystem function
6. Environmental and climate effects on community structure
7. Climate induced habitat degradation
8. Fish assemblage relationship with habitat health

9. Response of fish assemblages to a disturbance
10. Population connectivity
11. Habitat impact on recruitment
12. Impacts of invasive species of native fish stocks
13. Assessing impacts of artificial reefs
14. Community structure
15. Population distribution

It was found that there was no relationship between the question being asked and the method that was chosen for the project ($X^2 = 6.0206$, df = NA, p-value = 0.9652).

Methods recorded:

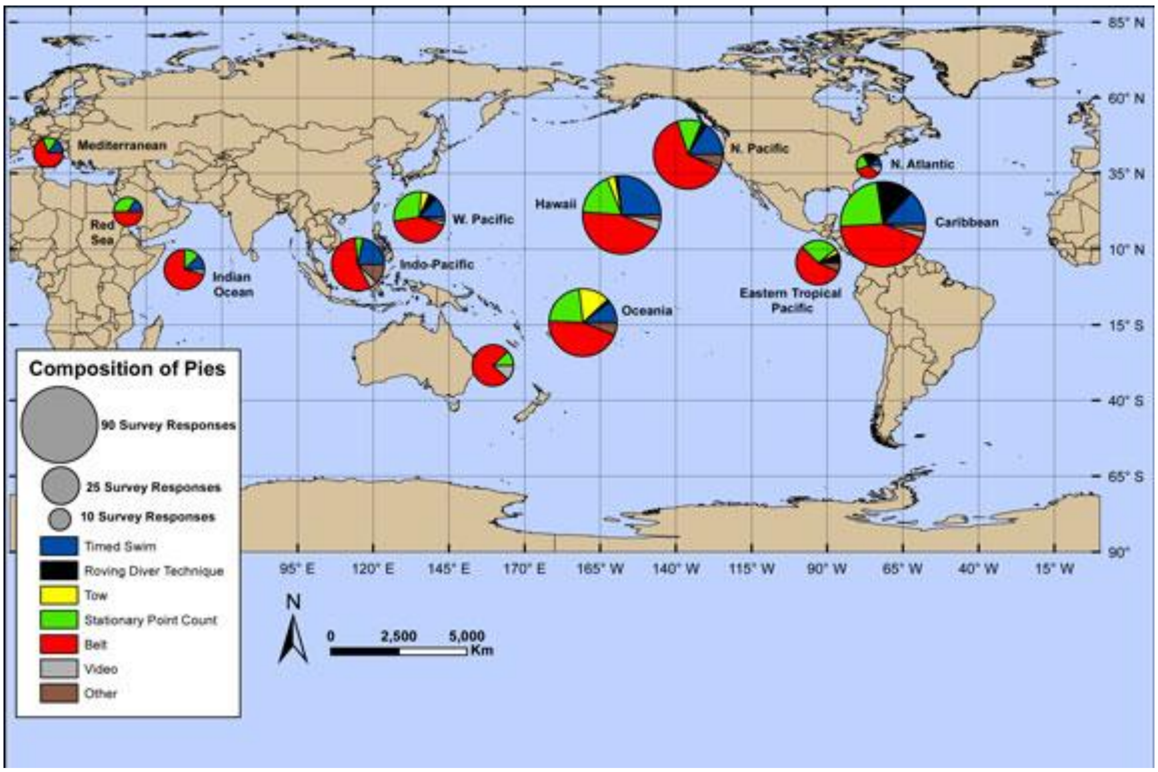
The following is a list of the survey methods that were recorded during the survey. A detailed description of each method is included in the "Methodologies Recorded" section of the website (cmbc.ucsd.edu/research/student_research/fish_surveys/methodology). The values correspond with the number of responses for each method.

Baited Video	8	Roving Diver	23
Belt	210	Side Scan Sonar	1
Comprehensive Surveys of Patch Reefs	2	Square plot samples	1
Distance Sampling	2	Standardized Reef Units	1
Genetic	1	Stationary Point Count	85
GPS based density survey	1	Stationary video	1
GPS based distance survey	1	Stereo Video	6
Jet Boot Surveys	1	Submersible	2
Laser Videogrammetry	1	Survey of individual coral bommies	1
Passive Acoustic	1	Timed Swim	56
Quadrat	4	Towed camera	1
ROV Sampling	1	Towed Diver	11
		Vertical Seawall Transects	1

The majority of these methods were used in a few places. Some researchers recorded using multiple methods so calculating the percentages of researchers using each method was calculated as individual replicates. 80% of researchers recorded that they use the belt transect method, 30% of researchers use the stationary point count method, and 27%

of researchers use some variation of a timed swim method that aimed at covering greater areas of reef and targeting larger bodied fish species.

The figure below shows the distribution of the methods that were recorded. The size of the pie diagram corresponds to the number of total responses from that area. The colors within the pie diagram indicate the percentage of researchers that recorded using that method in that region.



It was found that there was no relationship between the method that was used and the location where it was used (X^2=3.0455, df = 4, p-value = 0.7036).

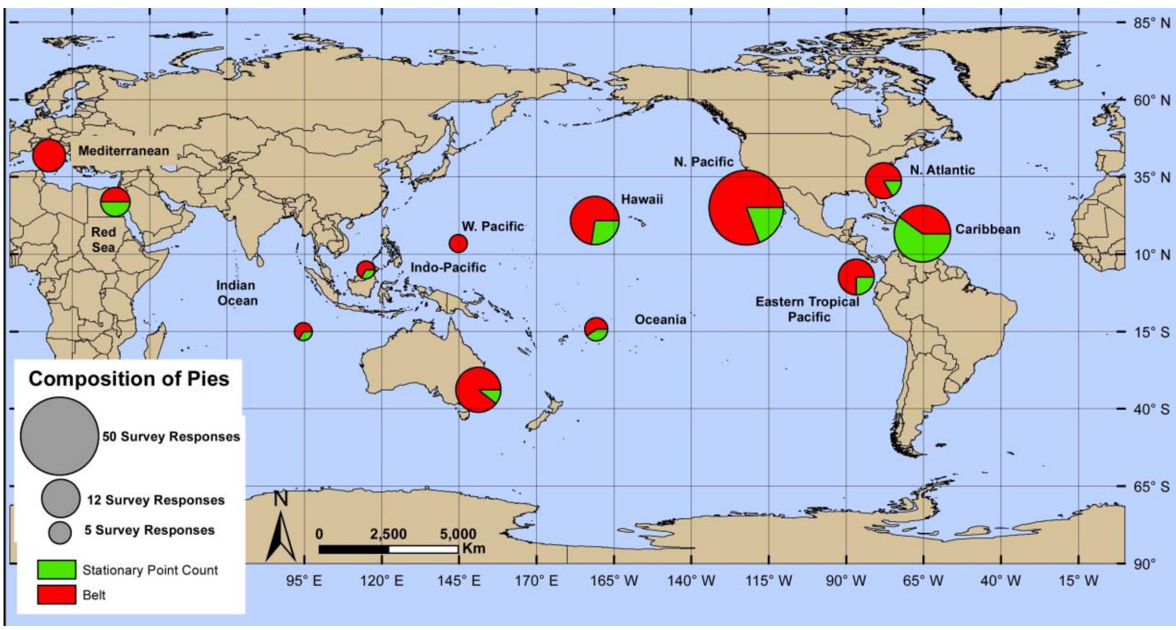
In order to quantify the data the 180 individual responses had to be lumped into 12 regions:

1. Red Sea
2. Florida/ Caribbean/ Brazil
3. Mediterranean
4. Indo Pacific/ Coral Triangle
5. Indian Ocean
7. Temperate/ North Pacific
8. Oceania
9. Micronesia/ Southern Japan
10. Australia
11. Hawaii

6. Eastern Tropical Pacific 12. Atlantic

In order to quantify the results of the methods that were being used in these locations we separated the belt transects and the stationary point counts from the rest of the methods. These two methods were the most popular methods used and were associated with the most argument of which of the two methods were most effective.

IP addresses were recorded with the survey data. Each IP address was linked to that individual's responses. We researched which region each IP address originated from and found that there was a significant relationship between the location of the researcher's home institution of place of work to the method that was chosen for the project (X^2 = 11.3263, df = 5, p-value = 0.0439). The map below shows that the majority of researchers whose home institution is in the region of the Caribbean drive the stationary point count method while the researchers in Australia, Hawaii, and the eastern Pacific are driving the use of the belt transect method.

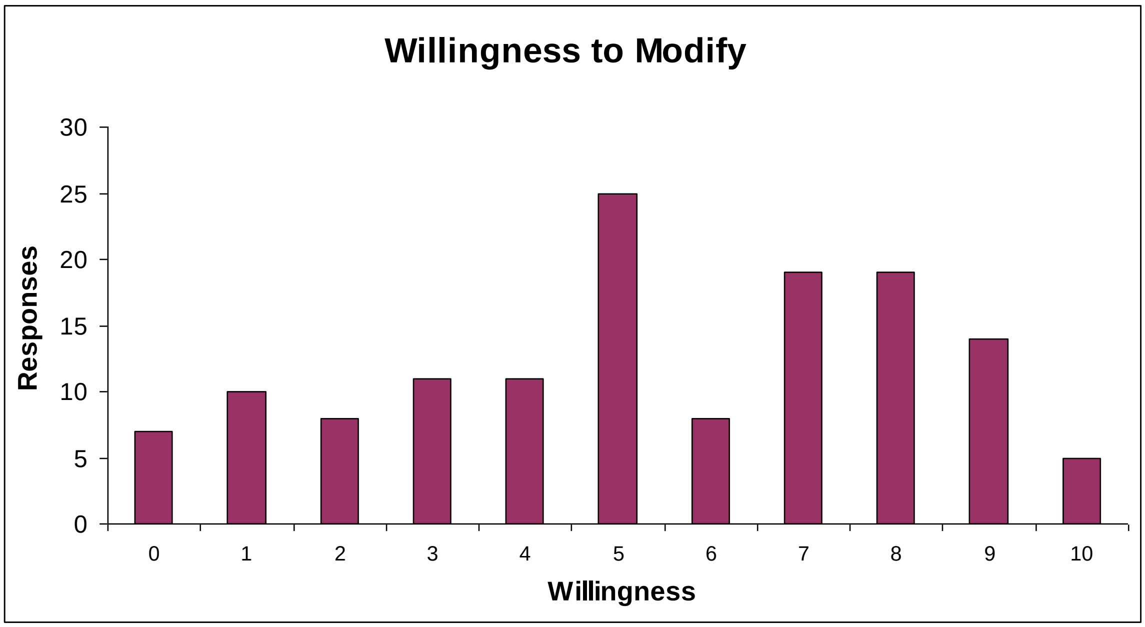


It was originally hypothesized that the belt transect would be associated with the longer standing projects but this was not the case. The method chosen for these projects were found to be independent of both study duration (X^2 = 2.4579, df = 4, p-value = 0.6958).

Standardizing methodologies and willingness to modify current protocols:

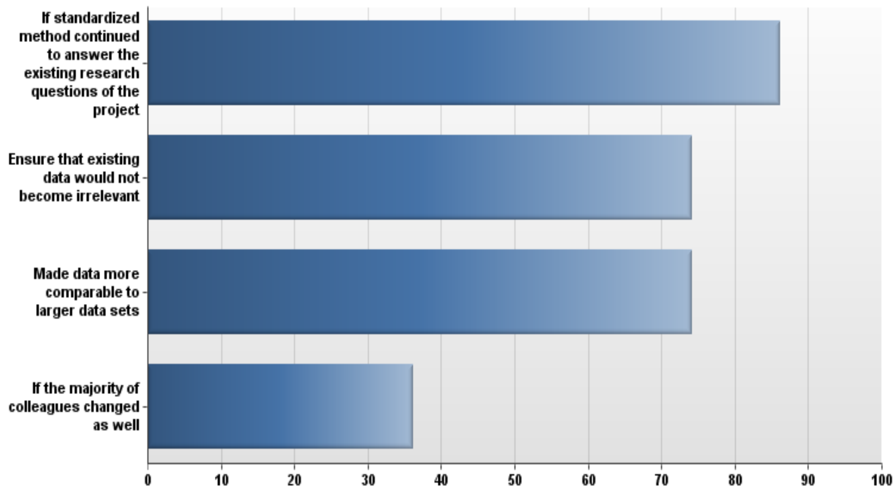
80% of the researchers said that they see a benefit in having a standardized method that would produce comparable data across regions.

Out of the researchers that said that they saw a benefit in standardizing methodologies, 76% said that they would be willing to significantly modify their existing protocols to a more standardized method. 40% of researchers that said they did not see a benefit in standardizing their protocols recorded that they would be willing to modify their protocols as well. The willingness to modify existing protocols to a standardized method was measured on a sliding scale from 0-10. 0 being that the researcher was not willing to modify their survey protocols at all and 10 being that the researcher is willing to completely adopt a new method. The mean willingness to modify was 5.25. The figure below shows the distribution of responses along the sliding scale of 0-10:



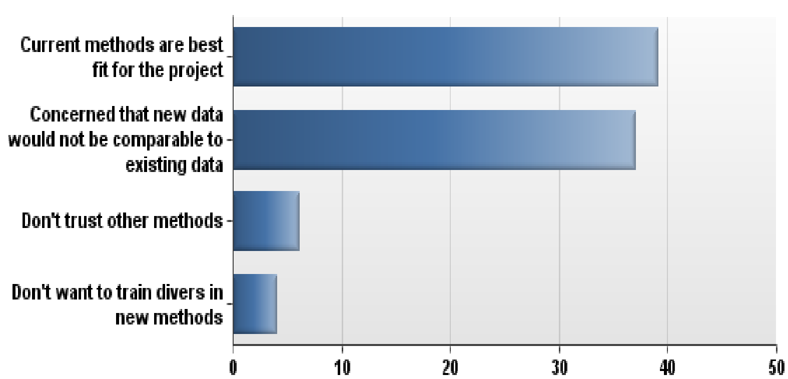
The individuals that did see a benefit in standardization said that they would be willing to modify if it ensured that:

1. The method would continue to answer the existing research question
2. Ensure that existing data would not become irrelevant or unusable
3. Made data more comparable to larger datasets.
4. If majority of colleagues changed as well



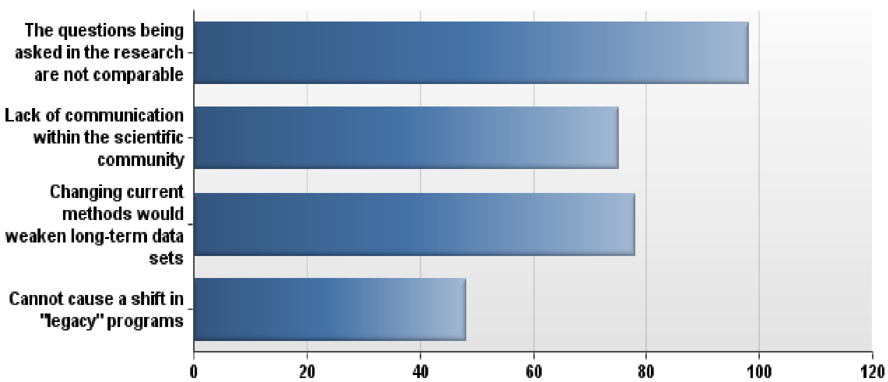
Those researchers that did not see a benefit in standardizing methodologies or were not willing to modify their existing protocols gave the following reasons:

1. Current methods are the best fit for the project
2. Concerned that new data would not be comparable to existing data
3. Don’t trust other methods
4. Don’t want to train divers in new methods



The survey then went on to ask the researchers, regardless of their position on standardizing methodologies, why a standardized method had not been established? The top answers were as follows:

1. The questions being asked in the research are not comparable
2. Lack of communication within the scientific community
3. Changing current methods would weaken long-term data sets
4. Cannot cause a shift in “legacy” programs



Statistically, the willingness for a researcher to change his/her existing methodology to a standardized method was independent of the motivation for the study the research question that was being asked, and how the method was developed. There was a relationship between the willingness of a researcher to modify their protocols to the duration of the study ($X^2 = 13.1556$, df = 3, p-value = 0.009). It was shown that the longer the duration of the study, and the greater the dataset size, the less willing people were to modifying their existing protocols.

Discussion:

It was shown that the majority of researchers are using the belt method, stationary point count, or a timed swim. Many of the researchers are using a suite of these methods to answer their research question as completely as possible. Many of the other methods recorded were variations of or additional tools for the methods mentioned above. For example, tow boarding or the use of propulsion devices such as jet boots can be viewed as a type of timed swim methodology. The addition of these tools makes it easier for divers to survey larger areas of reef in a certain amount of time. Biomass calculations can still be made since the survey is governed by time, there are start and end points marked, and the divers count and size fishes within a swath along their transect. Much of the video and use of lasers were employed while divers swam along a transect line. The video and laser was aimed at eliminating diver bias by creating a permanent record of the species observed and a reference for the size of the fishes. From the descriptions given of the methods and the research that was being conducted with the methods recorded, methodologies such as the rectangular plots, and standardized reef units were similar to the stationary point count method. It seemed that there was a pre-defined area of reef that was surveyed for a given amount of time. It will be very interesting to see where some of the more unique methods such as passive acoustics, and side scan sonar will go in the future with the measuring of diversity and abundance of fish assemblages.

After looking at the questions that researchers are trying to answer it became apparent that perhaps one single method would never be appropriate for all situations. It seems that with the diverse work being done that it might be more realistic to employ a suite of standardized methods that one can choose from depending on the question being asked or the region or environment in which they are working. It seems like the research community should focus on the inter-compatability of a few methods. From there the development of very good conversion factors could be calculated and we could begin to produce comparable data.

The research showed that there was no relationship between the method that was chosen and the question that was being answered. Comparisons between the belt transect and the stationary point count have shown very little difference between the two in accurately measuring fish densities (Samoilys and Carlos 2000). This implies that the method that is chosen for a project is largely influenced by the researcher's personal bias. There was no significant relationship found between the location where the work was recorded being conducted and the method chosen. It was originally hypothesized that region would influence which method was dominantly used, but it was found that region and method were not related. This shows again that the belt transect and stationary point count methods can both be effective and popular as tools in many regions.

A factor that did influence the method that was chosen was the location where the researcher was from. The data was showing that researchers that originate from the same region have a tendency to use the same methodologies no matter where they travel to work or what they are trying to answer. This makes sense since most of the researchers surveyed probably came from academic or governmental organizations that hopefully work together or communicate and collaborate with one another to some degree on a regional level where their home institution is located.

Willingness to modify and thoughts on standardization:

The biggest correlation that was found when dealing with researchers' willingness to modify their protocols to a standardized method was with the willingness to change and the size of the dataset. One of the most common reasons recorded that causes hesitation amongst researchers to adopt a standardized method was fear of losing or weakening existing data. Some of the "legacy" programs or studies that have been ongoing for a decade or more would be very hesitant to change methodologies if the common thought was that their existing data would become lost or irrelevant. If methodologies are to be standardized it must be taken into account that these larger, on going projects cannot become irrelevant. This issue could be solved through improving communication within the research community.

Besides the fear of losing existing data, many researchers that participated in this project expressed that egos and more established "legacy" programs would get in the way of ever developing a standardized method of surveying reef fishes.   It was said that even if a standardized method was developed that would ensure that existing data would not become irrelevant a standardized method would never be agreed upon because of peoples' pride. It was also largely stated that the lack of communication within the research community needs to improve drastically before any method can be agreed upon.

In order to successfully develop or adopt a method that will produce comparable data the research community must first start thinking outside of their immediate research area and remember that the majority of this work is for the greater good of our oceans on a global scale. This would include working in collaboration with other organizations that are not only working in the same region as one another but also collecting data to answer the same questions.

Conclusions:

According to the data that were collected during this study, standardizing survey methodologies, at least to a certain extent could be possible. The majority of the individuals who were surveyed see a benefit in standardization and a majority of those who see a benefit are willing to modify their protocols to some extent as long as their existing data does not become irrelevant. The idea of producing or adopting one method that will be effective in all regions and for all questions trying to be answered is a fallacy. A more realistic approach would be to adopt a group of methods for standardization that researchers can choose from depending on where they are working or what questions they are trying to answer. Conversion calculations could be developed from these few methods to account for the biases that are introduced by each.

Although the research community has shown that it sees importance in standardizing methodologies, this process is going to have to be driven internally from within the research community. It seems that since the choice of which method to use is driven regionally by where the research calls home, then the process of developing and adopting these standardized methods should start on a regional basis. We should capitalize on these regional patterns as a way of standardizing on a regional level. Communication and partnerships have to improve on a regional basis in order for this to succeed. New researchers entering this field should take the responsibility upon themselves to communicate with scientists who not only work in the same location of the research being conducted but communicate with researchers whose home institution or organization is neighboring their own.

It is interesting that when involved in such a selfless field as conservation that egos, pride, and biases get in the way of our ultimate goal, which is bettering the health of our ocean's resources. One of the most effective ways to better the health of our oceans is to provide managers and policy makers with the most complete and comparable datasets possible, this would ensure that managers can measure the impacts and comparisons of how our reefs are affected by certain events and activities so that they can make the most effective and educated management decisions possible. One way to provide managers with that information is to produce data that is comparable across regions. Producing comparable data is going to be accomplished through developing and implementing standardized survey methodologies that are effective across all regions.

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Appendix 1

1 Abu Dhabi
2 Aceh, Sumatra
3 Ahihi Kinau
4 Alabama
5 Aldabra Island
6 Alicante, Spain
7 Almeria, Spain
8 American Samoa
9 Anacapa Islands
10 Andavadoaka, Madagascar
11 Angel de la Guarda Isla
12 Arabian Gulf
13 Arabian Sea
14 Ashmore Reef
15 Assomption Island
16 Astove Island
17 Australia
18 Bahamas
19 Bali
20 Belize
21 Bolinao, Philippines
22 Bonaire
23 Brazil
24 British Columbia
25 Broward Co, Florida
26 Buck Island Reef NM, St. Croix
27 Cabo Pulmo
28 Caicos Islands
29 California
30 Cambodia
31 Cape Brett
32 Caribbean
33 Catalina Island
34 Cayman Islands
35 Central America
36 Central Mexico (Pacific)
37 Central Venezuela
38 Channel Islands
39 Chukchi Sea
40 Cocos Island
41 Conch Reef, Florida Keys
42 Cook Inlet
43 Costa Rica
44 Cozumel Island
45 Curacao
46 Dry Tortugas
97 Kingman Reef
98 Kipahulu
99 Kiribati
100 Kofiau, West Papua
101 Kuwait
102 Kwajalein Atoll
103 Lady Musgrave Reef
104 Lee Stocking Island
105 Line Islands
106 Lizard Island
107 Long Island Sound
108 Loreto Bay, Mexico
109 Madagascar
110 Magdalena Island
111 Maine
112 Malpello Island
113 Maputaland, South Africa
114 Marianas Islands
115 Marquesas
116 Marshall Islands
117 Massachusetts
118 Maui, Hawaii
119 Maunalua Bay
120 Mayotte Island
121 Mexico, Caribbean
122 Micronesia
123 Milolii
124 Mimiwhangata
125 Mokohinau Islands
126 Mombasa, Kenya
127 Monterey, CA
128 Moorea
129 Murcia, Spain
130 Natividad Island
131 Nayarit
132 NE Gulf of Mexico
133 Nelson-Marlborough, NZ
134 New Caledonia
135 New Ireland Province
136 New Providence Island
137 New South Wales
138 Northeast Canada
139 Northeast New Zealand
140 Northern California
141 Northwestern Hawaiian Islands
142 Oaxaca

47	Eastern Australia	143	Okinawa
48	Eastern Tropical Pacific	144	Oregon
49	Egypt	145	Palau
50	Eilat, Israel	146	Palm Beach, Florida
51	Elizabeth Reef	147	Palmyra
52	Fanning Island	148	Panama
53	Fiji	149	Papua New Guinea
54	Flores	150	Passage Canal, Alaska
55	Florida	151	Pelekane Bay
56	Flower Garden Banks	152	Pez Maya
57	France	153	Philippines
58	French Polynesia	154	Phoenix Islands
59	Frying Pan Shoals	155	Poor Knights Islands
60	Galapagos Islands	156	PRIA
61	Glovers Reef	157	Prince William Sound
62	Great Barrier Reef	158	Puako
63	Grenada	159	Puerto Morelos
64	Guam	160	Puerto Penasco
65	Guerrero	161	Puerto Rico
66	Gulf of Aqaba, Israel	162	Puget Sound
67	Gulf of Mexico	163	Pupukea
68	Gulf of Oman	164	Rapa Nui
69	Gulf of Thailand	165	Reunion Island
70	Hawaii	166	Rota
71	Indian Ocean	167	Saipan
72	Indonesia	168	San Clamente Island
73	Islas Marias	169	San Salvador, Bahamas
74	Israel, Mediterranean	170	Santa Catarina, Brazil
75	Israel, Red Sea	171	Santa Cruz Island
76	Italy	172	Seychelles
77	Jamaica	173	Shikmona/ Haifa, Israel
78	Japan	174	Sicily
79	Jordan	175	Sitka, Alaska
80	Juniper Island, Florida	176	Solomon Islands
81	Kahoolawe	177	Southeast Florida
82	Kalapana, HI	178	Southern California
83	Kalimantan	179	Southern Marianas Islands
84	Kaloko, HI	180	Southern Oregon
85	Kaupulehu	181	Southeast Australia
86	Kenai Peninsula	182	St Croix
87	Kiholo Bay, HI	183	St Kitts and Nevis
88	Tonga	184	St Vincent
89	Utila, Honduras	185	St. Pierre Island
90	Valparaiso, Chile	186	St. Thomas
91	Velondriake	187	Sulawesi
92	Virgin Islands	188	SW Gulf of California
93	Washington	189	Tahiti
94	West Hawaii	190	Tasmania
95	Western Australia, Ningaloo	191	Tinian
96	Zanzibar, Tansania		