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## **Final report on 'Extinction Resistance' for Conservation International Marine Management Areas Science program**

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### **Executive Summary**

**Status of Research.** The 'Extinction Resistance' workplan of the Marine Management Areas Science program was developed to improve understanding of the representation, status, and trends of species of global biodiversity conservation significance in marine management areas. The 'Extinction Resistance' workplan, initiated in Mar 2006, focused on two seascapes – the Eastern Tropical Pacific (Ecuador, Colombia, Panama, Costa Rica) and the South-west Pacific (Samoa, Fiji) – as well as synthesizing global lessons from these. In the former region, the project operated partly through graduate student research (at University of Tasmania), while in the latter it supported recruitment of a position in SPREP. This Aug 2010 report summarizes the results of four years of implementation of the workplan to date; while this comprises the final report to the Marine Management Areas Science, efforts supported by leveraged fundraising are anticipated to continue for at least another two years (in particular through completion and publication of the supported graduate student's research; and through a Fulbright Fellowship currently awarded to PI Edgar to investigate the value of MPAs for conservation of threatened marine species).

**Results to Date.** The central high-level finding of the 'Extinction Resistance' workplan is that marine management areas, at least in the Eastern Tropical Pacific and South-west Pacific seascapes, provide an effective framework for the conservation of species of global biodiversity significance. Specifically, in the Eastern Tropical Pacific, marine management areas represent: populations of 83% of the 93 threatened species; 67% of Alliance for Zero Extinction sites (holding the entire global population of one or more highly threatened species); and more than half of site occurrences for 60% of threatened species. However, it is clear that biodiversity conservation benefits afforded by marine management areas require many years, probably many decades, to fully manifest; thus, empirical data are not yet available to quantify the effectiveness of marine management areas in safeguarding species. The establishment of long-term, standardized monitoring programs in such sites, harnessing specialist citizen science and

supporting in-country capacity building, will be essential to fully answer this key question. The 'Extinction Resistance' workplan incorporated field monitoring, in collaboration with other initiatives including the Ecological Monitoring component of the MMAS project, to initiate this critically important work.

**Data.** The 'Extinction Resistance' workplan comprised systematic compilation and permanent archiving of two major datasets. The first of these was the assessment of marine species extinction risk against the IUCN Red List categories and criteria, for all coral species (848 species), Galápagos endemic macroalgae (74 species), and Eastern Tropical Pacific endemic fish species (1,149 species). These data are archived in the IUCN SSC Species Information Service. The second dataset comprises the site-level distribution of threatened species, identifying "key biodiversity areas" as targets for marine management area initiatives. This work identified 54 such sites in Ecuador (including 49 in the Galápagos alone), eight in Colombia, 13 in Panama, five in Costa Rica, one in the French island of Clipperton, and seven in Samoa. These data will be archived in the World Biodiversity Database, co-managed between Conservation International and BirdLife International.

**Publications and Deliverables.** A total of five peer-reviewed scientific papers have been published as a direct result of the 'Extinction Resistance' workplan: two in *'Aquatic Conservation: Marine and Freshwater Ecosystems'*, one in *'Global Change Biology'*, one in *'Animal Conservation'*, and one in *'Science'*, as well as two book chapters in edited volumes, one guidelines manual, one technical report, and one field logbook. A further three scientific papers are in preparation for submission to peer-reviewed journals. Five presentations have been given at professional scientific and managers meetings on the results of the work. In addition, the influence of the 'Extinction Resistance' workplan now extends widely across the Pacific through facilitation of a collaborative project with PI Edgar as Chief Investigator 'Incorporation of Vulnerability and Irreplaceability into Marine Protected Area Planning'. The project, which has been primarily funded by the Australian Research Council (ARC) and Australian government agencies, has generated a number of publications addressing the same topic.

**Science to Action.** The most notable science-to-action product of the project was a logbook for ongoing monitoring of threatened Eastern Tropical Pacific marine species by recreational divers, designed and implemented in collaboration with the Charles Darwin Research Station. In addition, the project complemented the establishment of baseline field monitoring at four sites through the Eastern Tropical Pacific, engaging 23 specialists in the process (most of them nationals of Ecuador, Colombia, Panama, or Costa Rica).

**Capacity Building.** The project, along with leveraged funding from the ARC, provided full support for the PhD studentship for Monica Calvopiña, a native of the Galápagos, at the University of Tasmania. Her anticipated graduation date is Dec 2011. 'Extinction Resistance' also supported contracts to seven in-country early-career specialists for data compilation, and facilitated training of nationals from Ecuador, Colombia, Costa Rica and Panama in field identification during surveys. Finally, the project leveraged a successful application for a prestigious Fulbright fellowship awarded to PI Edgar, enabling follow-up and additional global-level analyses after the completion of the project's internal workplan.

## 1. Introduction and Status of Research

The Conservation International Marine Management Areas Science (MMAS) project aimed to evaluate the effectiveness of marine management areas from a range of perspectives, including biodiversity, ecosystem services, and socio-economic costs and benefits. In order to achieve the first of these, it is necessary to understand which species of global biodiversity conservation significance (e.g., those threatened with extinction) occur in existing marine management areas, and the status and trends of these. In March 2006, MMAS therefore established a workplan to examine 'Extinction Resistance' in marine management areas, with an initial focus in the Eastern Tropical Pacific (Ecuador, Colombia, Panama, Costa Rica) and the South-west Pacific (Fiji, Samoa).

This final report builds on the first three reports delivered to MMAS (September 2006, August 2007, June 2008), to report on all activities and results of the 'Extinction Resistance' workplan. We summarize these activities under six categories: results to date; data; publications and deliverables; science to action; and capacity building. While this comprises the final report to the Marine Management Areas Science program under the 'Extinction Resistance' workplan, efforts supported by leveraged fundraising are anticipated to continue for at least another two years (in particular through completion and publication of the supported graduate student's research; and of PI Edgar's Fulbright fellowship).

## 2. Results to Date

The central high-level finding of the 'Extinction Resistance' workplan is that marine management areas, at least in the Eastern Tropical Pacific and South-west Pacific seascapes, provide an effective framework for the conservation of species of global biodiversity significance. Here, we document three key aspects of this.

First, the great majority of the threatened marine species of the Eastern Tropical Pacific and South-west Pacific seascapes occur in marine management areas (Table 1). In the Eastern Tropical Pacific, 83% of 93 threatened species (and of 78 threatened endemic species) of corals, macroalgae, and fishes have populations represented in marine management areas.

In Samoa, although 71 threatened marine species are known to occur in the country, 52 of these are corals for which it proved impossible to trace site level records within the project's timeframe, and a further 14 are sharks (*Carcharhinus longimanus*, *Isurus oxyrinchus*, *Nebrius ferrugineus*, *Negaprion acutidens*, *Rhincodon typus*, *Stegostoma fasciatum*), rays (*Himantura gerrardi*), fish (*Hippocampus kuda*, *Plectropomus areolatus*, *Plectropomus laevis*, *Rhynchobatus djiddensis*, *Sphoeroides pachygaster*, *Thunnus obesus*), and cetaceans (*Physeter macrocephalus*) which only occur sporadically within coastal sites. All of the remaining five Samoan threatened marine species – three fishes (*Bolbometopon muricatum*, *Cheilinus undulates*, *Epinephelus lanceolatus*) and two turtles (*Chelonia mydas*, *Eretmochelys imbricata*) – occur in at least one marine management area.

**Table 1.** Representation of threatened species in marine management areas.

Taxon	Threatened species	Threatened species represented in marine management areas
Eastern Tropical Pacific endemic corals	6	6 (100% represented)
Galápagos endemic macroalgae	13	10 (77% represented)
Eastern Pacific endemic fishes	59	49 (83% represented)
Eastern Pacific widespread fishes	15	12 (80% represented)
<i>Eastern Tropical Pacific Total</i>	93	77 (83% represented)
Samoa groupers and turtles	5	5 (100% represented)

Second, we consider the 26 Eastern Tropical Pacific threatened species for which the entire global distribution is restricted to a single site. There are 10 such sites in the region, and marine management areas safeguard six of them (60%), and 17 (65%) of the species (Table 2). Six of these sites hold the entire global population of one or more species assessed as Critically Endangered or Endangered on the IUCN Red List, and so meet the criteria for “Alliance for Zero Extinction” (AZE; <http://www.zeroextinction.org>) sites. Between them, these sites hold six Critically Endangered and two Endangered single-site endemic species (as well as, incidentally, five Vulnerable species). Four of these AZE sites are marine management areas (67%), safeguarding five of the region’s eight highly threatened single site endemic species (63%).

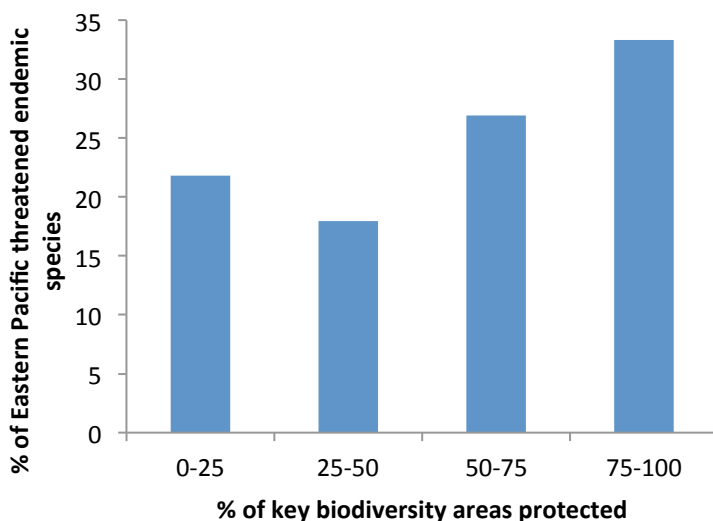
**Table 2.** Marine key biodiversity areas holding single site endemic species. Whether currently recognised as an area protected from fishing and other threats (PA), the level of threat for the species (i.e. IUCN Red List status), and whether an AZE site is also shown.

Key biodiversity area	PA?	AZE?	Species	Status
<b><i>Eastern Tropical Pacific</i></b>				
Floreana conservation zone (Galápagos, Ecuador)	Y	Y	<i>Desmarestia tropica</i>	CR
			<i>Gracillaria skottsbergii</i>	CR
West Fernandina tourism zone (Galápagos, Ecuador)	Y	Y	<i>Dictyota galapagensis</i>	CR
Santa Cruz fishing zone, (Galápagos, Ecuador)	N	Y	<i>Myriogramme kylinii</i>	CR
			<i>Acrosorium papenfussii</i>	VU
			<i>Pseudolaingia hancockii</i>	VU
			<i>Ogilbia galapagosensis</i>	VU
Isla Plata (Ecuador)	Y	Y	<i>Triakis acutipinna</i>	EN
Malpelo (Colombia)	Y	N	<i>Axoclinus rubinoffi</i>	VU
			<i>Lepidonectes bimaculatus</i>	VU
			<i>Chriolepis lepidota</i>	VU
			<i>Acanthemblemaria stephensi</i>	VU
Coiba (Panama)	Y	Y	<i>Millepora boshmai</i>	CR
			<i>Pocillopora inflata</i>	VU

PA_NewUnit_6 (Panama)	N	Y	<i>Gobulus birdsongi</i>	CR
			<i>Gobiosoma homochroma</i>	EN
			<i>Urotrygon simulatrix</i>	VU
PA_NewUnit_10 (Panama)	N	N	<i>Urotrygon reticulata</i>	VU
Cocos (Costa Rica)	Y	N	<i>Axoclinus cocoensis</i>	VU
			<i>Chriolepis dialepta</i>	VU
			<i>Gobiesox woodsi</i>	VU
			<i>Tomicodon vermiculatus</i>	VU
			<i>Gillellus chathamensis</i>	VU
			<i>Acanthemblemaria atrata</i>	VU
			<i>Ogilbia cocoensis</i>	VU
Clipperton (France)	N	N	<i>Epinephelus clippertonensis</i>	VU

Third, we ask to what degree marine management areas represent the entire range of threatened species, by asking, for each Eastern Tropical Pacific threatened endemic species, what proportion of the sites at which the species occurs are represented in marine management areas (Figure 1). The results are encouraging: 60% of Eastern Tropical Pacific threatened endemics have management in place at more than half of their sites, and a third have management in place at more than three-quarters of their sites.

**Figure 1.** Frequency distribution of the proportions of key biodiversity areas safeguarded as marine management areas, for 78 threatened endemic corals, Galápagos endemic macroalgae, and endemic fishes in the Eastern Pacific.



Nevertheless, it is clear that biodiversity conservation benefits afforded by marine management areas require many years, probably many decades, to fully manifest; thus, empirical data are not yet available to quantify the effectiveness of marine management areas in safeguarding species. The establishment of long-term, standardized monitoring programs in such sites,

harnessing specialist citizen science and supporting in-country capacity building, will be essential to fully answer this key question. The 'Extinction Resistance' workplan incorporated field monitoring, in collaboration with other initiatives including the Ecological Monitoring component of the MMAS project, to initiate this critically important work.

### 3. Data

#### 3.1. Assessment of species extinction risk

In order to complete the project's goals, the initial task was to compile a list of target threatened species. A major need recognized within the Extinction Resistance workplan was to extend threat assessments beyond the wide-ranging charismatic megavertebrates to the more site-attached species, which should benefit most from MMA interventions. This task is non-trivial as threat assessments had not been systematically undertaken anywhere worldwide prior to our project for any of the marine taxa most likely to benefit from marine management areas (i.e., corals, reef fishes, macroalgae). Over the period of the project, we developed collaborations with specialists to compile data on the distribution of, and threats to, marine biodiversity, especially in the Eastern Tropical Pacific, with primary focus on occurrence and trends in marine management areas. This work has comprised two strands: seven contracts with specialists to conduct initial data compilation; and participation in five workshops, held in conjunction with IUCN, to review these published data and supplement them with unpublished information. These data are archived in the IUCN SSC Species Information Service. Data compilation is now complete for all coral species, for Galápagos endemic macroalgae, and for Eastern Tropical Pacific endemic fish species, as follows:

##### ***Corals globally (845 scleractinian species, 3 hydrocoral species)***

*Contract:* Angel Chiriboga (CDRS/Brown University), Jun–Sep 2006.

*Workshops:* Puerto Ayoro, Ecuador, 27-28 May 2006 (89 species); Anilao, Philippines, July 2007 (737 species).

*Participants (Workshop I):* Stuart Banks (CDRS), Angel Chiriboga (CDRS/Brown University), Jorge Cortez (CIMAR/Universidad de Costa Rica), Graham Edgar (University of Tasmania), Hector Guzman (STRI), Scott Henderson (CI-Galápagos), Mariana Vera (CDRS). Javier Bello (CI-Mesoamerica) was invited to facilitate linkage between the ETPS and Gulf of California, but was unable to attend due to logistical problems. Peter Glynn (University of Miami) also contributed to data compilation, but was unable to attend the workshop.

*Facilitators (Workshop I):* Kent Carpenter (IUCN/ODU) and Caroline Pollock (IUCN).

*Participants (Workshop II):* Greta Aeby (Hawaii Institute), Andy Bruckner (NOAA), Lyndon DeVantier (Coral Reef Research), Alasdair Edwards (Newcastle University), Doug Fenner (American Samoa), Gregor Hodgson (Reefcheck), Bert Hoeksema (National Museum, Netherlands), Ofri Johan (Indonesia), W. Licuanan (De La Salle University, Philippines), Domingo Ochavillo (Reefcheck), David Obura (CORDIO, Kenya), Miledel Quibilan (CI-Philippines), Zoe Richards (James Cook University), Alex Rogers (Zoological Society of London), M. Syahrir, Emre Turak (Cormec, France), Elizabeth Wood (Marine Conservation Society).

*Facilitators (Workshop II):* Moonyeen Alava (CI-Philippines), Kent Carpenter (IUCN/ODU), Hubert Froyalde (CI-Philippines), Suzanne Livingstone (IUCN/ODU), Mike Palomar (CI-Philippines), Beth Polidoro (IUCN/ODU), Caroline Pollock (IUCN), Jonnell Sanciangco (IUCN/ODU), Jennifer Smith (IUCN/ODU), Simon Stuart (IUCN), Dana Zebrowski (ODU).

*Synergies with other projects:* Darwin Initiative, GMSA.

*Key results:* Assessments for the 10 Galápagos endemics were published on the 2007 IUCN Red List, including 3 CR and 1 VU species. Assessments for the remaining 838 species were published on the 2008 IUCN Red List, including 5 CR, 25 EN, and 201 VU species.

### ***Galápagos endemic macroalgae (74 species)***

*Contract:* Angel Chiriboga (CDRS/Brown University), Jun–Sep 2006.

*Workshop:* CDRS, Puerto Ayora, Ecuador, 29–30 May 2006.

*Participants:* Stuart Banks (CDRS), Angel Chiriboga (CDRS/Brown University), Graham Edgar (University of Tasmania), Lauren Garske (University of California Davis), Scott Henderson (CI-Galápagos), Kathy Ann Miller (University of California Berkeley).

*Facilitators:* Kent Carpenter (IUCN/Old Dominion Univ), Graham Edgar (University of Tasmania) and Caroline Pollock (IUCN).

*Synergies with other projects:* Darwin Initiative, GMSA.

*Key results:* Assessments for all 74 species were published on the 2007 IUCN Red List, including 10 CR, 1 EN, and 4 VU species.

### ***Eastern Tropical Pacific endemic fishes (1,149 species)***

*Contracts:* Jonnell Sanciangco (ODU), Apr–Oct 2006; Arturo Dominici (Universidad de Panama), Feb–Jun 2007; Beatriz Medina (STRI), Mar–Jun 2007; Diego Barbeche (STRI), Mar–Jul 2007; Beth Polidoro (IUCN/ODU), Oct 2007.

*Workshops:* STRI, Panama City, Panama, 21–25 May 2007 (728 species); San Jose, Costa Rica, 28 April–3 May 2008 (421 species)

*Participants (Workshop I):* Arturo Acero (Colombia), Gerry Allen (Western Australian Museum), Diego Barbeche (STRI), Enrique Barraza (El Salvador), Philippe Bearez (MNHM, Paris), Sandra Bessudo (Fundación Malpelo), Ricardo Betancur (Auburn University), Bill Bussing (Universidad de Costa Rica), Labbish Chao (Manaus), Alejandro Cotto (Nicaragua), Arturo Dominici (Universidad de Panama), Graham Edgar (University of Tasmania), Hector Espinoza-Perez (UNAM), Lloyd Findley (Mexico), Nikita Gaibor (Instituto Nacional de Pesca, Ecuador), Hector Guzman (STRI), Phil Hasting (University California San Diego), Scott Henderson (CI-Galápagos), John McCosker (California Academy of Sciences), Beatriz Medina (STRI), Godfrey Merlen (Galápagos National Park Service), Tom Munroe (NMHM, Paris), Fernando Rivera (Ecuador), Ross Robertson (STRI), Efrain Rubio (Universidad de Valle), Alvaro Segura (WWF-Costa Rica), James Van Tassell (Hofstra University/NMNH), Fernando Zapata (Universidad de Valle).

*Facilitators (Workshop I):* Kent Carpenter (IUCN/ODU), Will Crosse (CI), Graham Edgar (University of Tasmania), Matt Foster (CI), Mike Hoffmann (IUCN), Suzanne Livingstone (IUCN/ODU), Beth Polidoro (IUCN/ODU), Marco Quesada (CI-Mesoamerica), Jennifer Smith (IUCN/ODU).

*Participants (Workshop II):* Bill Bussing (Universidad de Costa Rica), Bruce Collett (Smithsonian), Arturo Dominici (University of Panama), W. Eschmeyer (California Academy of Sciences), Ian

Harrison (American Museum of Natural History), T. Iwamoto (California Academy of Sciences), T. Munroe (Smithsonian), J. Nielsen (Denmark), Ross Robertson (STRI), W. Smith-Vaniz (US Fish and Game, Florida), J. Tyler (Smithsonian).

*Facilitators (Workshop II):* Kent Carpenter (IUCN/ODU), Suzanne Livingstone (IUCN/ODU), Beth Polidoro (IUCN/ODU), Jennifer Smith (IUCN/ODU).

*Synergies with other projects:* GMSA, Walton, UNF-GCF.

*Key results:* Assessments for all 1,149 species were completed and should soon be ratified for inclusion on the IUCN Red List.

In addition to these taxa, mangrove and seagrass species have also been globally assessed by the IUCN GMSA, along with all marine mammal, seabird, marine turtle, grouper, seahorse, shark, and ray species. Additional important groups that remain to be assessed include echinoderms, molluscs, and macroalgae (beyond the Galápagos endemics).

### 3.2. Identification of sites of global biodiversity conservation significance

With the evaluation of species extinction risk for the Eastern Tropical Pacific and South-west Pacific in hand, the next step necessary to evaluate representation, status, and trends of these species in marine management areas is to identify sites at which they occur – both within and beyond existing marine management areas.

For the Eastern Tropical Pacific, this process was led by Monica Calvopiña, as part of the requirements for her PhD dissertation at the University of Tasmania. The results of the process are tabulated below and are in preparation for publication in a peer reviewed journal. For the South-west Pacific, the process was led by Paul Anderson, an analyst hired by SPREP jointly supported by project funding and a number of other leveraged resources.

Country	Marine key biodiversity areas	Marine management areas
<b><i>Eastern Tropical Pacific</i></b>		
Ecuador (mainland)	5	1 (20%)
Ecuador (Galápagos)	49	26 (53%)
Colombia	8	2 (25%)
Panama	13	2 (15%)
Costa Rica	5	1 (20%)
France (Clipperton)	1	0 (0%)
<b><i>South-west Pacific</i></b>		
Samoa	7	3 (43%)

### 4. Publications and Deliverables

A total of five peer-reviewed scientific papers have been published as a direct result of the 'Extinction Resistance' workplan:

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Edgar, G.J., Banks, S., Bensted-Smith, R., Calvopiña, M., Chiriboga, A., Garske, L.E., Henderson, S., Miller, K.A., & Salazar, S. (2008) Conservation of threatened species in the Galapagos Marine Reserve through identification and protection of marine Key Biodiversity Areas. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18: 955–968.

Edgar, G.J., Langhammer, P.F., Allen, G., Brooks, T.M., Brodie, J., Crosse, W., De Silva, N., Fishpool, L., Foster, M.N., Knox, D., McCosker, J.E., McManus, R., Miller, A., & Mugo, R. (2008) Key Biodiversity Areas as globally significant target sites for the conservation of marine biological diversity. *Aquatic Conservation: Marine and Freshwater Ecosystem* 18: 969–983.

Edgar, G.J., Banks, S.A., Brandt, M., Bustamante, R.H., Chiriboga, A., Earle, S.A., Garske, L.E., Glynn, P.W., Grove, J.S., Henderson, S., Ickman, C.P.H., Miller, K.A., Rivera, F. & Wellington, G.M. (2009) El Niño, grazers and fisheries interact to greatly elevate extinction risk for Galapagos marine species. *Global Change Biology*. (Covered by the BBC, “Galapagos Islands are transformed”, [http://news.bbc.co.uk/earth/hi/earth\\_news/newsid\\_8395000/8395075.stm](http://news.bbc.co.uk/earth/hi/earth_news/newsid_8395000/8395075.stm), M. Walker, 4 Dec 2009).

Bass, D., De Silva, N., & Anderson, P. (2010) Applying thresholds to identify Key Biodiversity Areas for Marine Turtles in Melanesia. *Animal Conservation*.

Carpenter, K.E., Livingstone, S.R., Abrar, M., Aeby, G., Aronson, R.B., Banks, S., Bruckner, A., Chiriboga, A., Cortés, J., Delbeek, J.C., DeVantier, L., Edgar, G.J., Edwards, A.J., Fenner, D., Guzman, H.M., Hoeksema, B.W., Hodgson, G., Johan, O., Licuanan, W.Y., Lovell, E.R., Moore, J.A., Obura, D.A., Ochavillo, D., Polidoro, B.A., Precth, W.F., Quibilan, M.C., Reboton, C., Richards, Z.T., Rogers, A.D., Sanciangco, J., Sheppard, A., Sheppard, C., Smith, J., Stuart, S., Turak, E., Veron, J.E.N., Wallace, C., Weil, E. & Wood, E. (2008) One third of reef-building corals face elevated extinction risk from climate change and local impacts. *Science* 321: 560–563.

A further three scientific papers are in preparation for submission to peer-reviewed journals. In addition, the project has produced two book chapters in edited volumes, one guidelines manual, one technical report, and one field logbook:

Edgar, G.J., Russ, G.R. & Babcock, R.C. (2007) Marine protected areas. Pp. 533–555 in Connell, S. & Gillanders, B.M. (eds.) *Marine Ecology*. Oxford University Press, Oxford, UK.

Polidoro, B.A., Livingstone, S.R., Carpenter, K.E., Hutchinson, B., Mast, R.B., Pilcher, N.J., Sadovy de Mitcheson, Y. & Valenti, S.V. (2008) Status of the world’s marine species. Pp. 55–65 in Vié, J.-C., Hilton-Taylor, C. & Stuart, S.N. (eds.) *Wildlife in a Changing World*. IUCN, Gland, Switzerland.

Conservation International (2008) *Guidebook for the Identification, Delineation and Prioritization of Marine Key Biodiversity Areas: Global Site Conservation Targets for the Marine Environment*. Conservation Learning and Practice Series. Conservation International, Arlington, USA.

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Conservation International – Pacific Islands Programme, Ministry of Natural Resources and Environment, Secretariat of the Pacific Regional Environment Programme (2009) *Priority Sites for Conservation in Samoa: Key Biodiversity Areas*. South Pacific Regional Environment Programme, Apia, Samoa.

Calvopiña, M. & Edgar, G. (2008) *Threatened Marine Species Eastern Tropical Pacific Region: Guide and Logbook*. CDRS, Ecuador.

Pdf reprints for all of these publications are provided in Appendix III of this report.

The 'Extinction Resistance' workplan has also directly facilitated several additional publications generated through the associated Australian Research Council project 'Incorporation of Vulnerability and Irreplaceability into Marine Protected Area Planning':

Barrett, N.S. & Edgar, G.J. (2010) Distribution of benthic communities in the fjord-like Bathurst Channel ecosystem, south-western Tasmania, a globally anomalous estuarine protected area. *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Beck, M.W., Brumbaugh, R.D., Airoidi, L., Carranza, A., Coen, L.D., Crawford, C., Defeo, O., Edgar, G.J., Hancock, B., Kay, M., Lenihan, H., Luckenbach, M.W., Toropova, C.L. & Zhang, G. (2010) Shellfish reefs at risk globally and recommendations for ecosystem revitalization. *BioScience*.

Edgar, G.J., Barrett, N.S. & Stuart-Smith, R.D. (2009) Exploited reefs protected from fishing transform over decades into conservation features otherwise absent from seascapes. *Ecological Applications* 19: 1967–1974.

Edgar, G.J., Davey, A., Kelly, G., Mawbey, R.B. & Parsons, K. (2010) Biogeographical and ecological context for managing threats to coral and rocky reef communities in the Lord Howe Island Marine Park, south-western Pacific. *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Edgar, G.J., Last, P.R., Barrett, N.S., Gowlett-Holmes, K., Driessen, M. & Mooney, P. (2010) Conservation of natural wilderness values in the Port Davey marine and estuarine protected area, south-western Tasmania. *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Edgar, G.J. & Stuart-Smith, R.D. (2009) Ecological effects of marine protected areas on rocky reef communities: a continental-scale analysis. *Marine Ecology Progress Series* 388: 51-62.

Last, P.R., White, W.T., Gledhill, D., Hobday, A.J., Brown, R., Edgar, G.J. & Pecl, G. (2010) Long-term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices. *Global Ecology and Biogeography*.

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Five presentations have been given at professional scientific meetings on the results of the work:

Edgar, G.J., Banks, S. & Brooks, T. *The need for vulnerability and irreplaceability to be included within MPA planning*. XXI Society for Conservation Biology, Port Elizabeth, South Africa, 1–5 Jul 2007.

Edgar, G.J. *Biogeographic relationships and threats associated with marine fish faunas at four World Heritage Sites in the Eastern Tropical Pacific*. XXII Society for Conservation Biology, Chattanooga, USA, 14–18 Jul 2008.

Edgar, G.J. , Banks, S., Bessudo, S., Cortez, J., Guzman, H. & Zapata, F. *A scientific network for marine ecological monitoring across the Eastern Tropical Pacific*. Eastern Tropical Pacific MPA Managers Workshop, Galápagos, Ecuador, 18 Apr 2009.

Edgar, G.J. & Banks, S. *Catastrophic changes to inshore benthic communities following oceanographic warming events in the Galapagos archipelago*. International Symposium Climate Change Effects on Fish and Fisheries: Forecasting Impacts, Assessing Ecosystem Responses, and Evaluating. Sendai, Japan, 25–29 Apr 2010.

Edgar, G.J., Banks, S. & Ruiz, D. Symposium *How resilient are Galapagos rocky reef communities to recent El Niños?* Symposium “ENSO in the Galapagos: a model system for studying ecological effects of climate change in the ocean.” Ecological Society of America, Pittsburgh, USA, 1–6 Aug 2010.

## **5. Science to Action**

The most notable science-to-action product of the project was a dive tourism guide and logbook for ongoing “citizen science” monitoring of the distribution and population trends of threatened Eastern Tropical Pacific marine species by recreational divers, designed and implemented in collaboration with the Charles Darwin Research Station, to ensure effective dissemination and maintenance. This guide was printed and distributed to dive organizations across the region in 2008. We are in the process of analyzing data resulting from uptake of the logbook, and preparing results for publication in a peer-reviewed journal.

The “Extinction Resistance” data compilation work was complemented by our participation in a set of field activities designed to harmonize monitoring efforts underway in the relevant regions with the project. This broader regional monitoring program involved a large number collaborating agencies with principal coordination by CI-Galápagos, and with additional project funding from the “Ecological Monitoring” component of MMAS in the Eastern Tropical Pacific, the Walton Family Foundation seascape project, the UNF/GCF, the Darwin Initiative, STRI, CIMAR (Universidad de Costa Rica), Fundación Malpelo, and the Charles Darwin Foundation. Our participation ensured that observations of the population trends for threatened and endemic species were explicitly included within the MMAS “Ecological Monitoring” program,

and in other monitoring protocols underway in our focal regions. Importantly, we now have baseline data on the distribution and population densities of numerous threatened and endemic species in marine management areas across the Eastern Tropical Pacific that can be followed through time. To date, we have been involved in four field projects:

***Galápagos (Islas Marchena, Darwin and Wolf), Ecuador, 16–27 May 2006***

*Lead:* Stuart Banks (CDRS).

*Participants:* Angel Chiriboga (CDRS/Brown University), Jorge Cortes (CIMAR/Universidad de Costa Rica), Terry Dawson (University of Edinburgh), Sylvia Earle (CI), Graham Edgar (University of Tasmania), Peter Glynn (University of Miami), Scott Henderson (CI-Galápagos), Cleve Hickman (Washington and Lee University), Mariana Vera (CDRS).

*Key results:* Surveys were undertaken covering a range of taxa, with particular emphasis on assessing the health of coral reef communities and documenting the abundance of endemic fish species in different MMA management zones.

***Isla de Coco, Costa Rica, 31 Aug – 10 Sep 2006***

*Lead:* Jorge Cortes (CIMAR/Universidad de Costa Rica).

*Participants:* Juan José Alvarado (CIMAR/Universidad de Costa Rica), Stuart Banks (CDRS), Isaac Chinchilla (Área de Conservación Marina, Isla del Coco), Angel Chiriboga (CDRS/Brown University), Graham Edgar (University of Tasmania), Cindy Fernández (MarViva), Ana Fonseca (CIMAR/Universidad da Costa Rica), Mónica Naranjo (MarViva), Marco Quesada (CI-Mesoamerica).

*Key results:* Data collected provides a quantitative baseline for future monitoring of sessile invertebrates, mobile macroinvertebrates, and fishes, including several endemic species, and allows an evaluation of the effectiveness of a fully-protected marine management area.

***Malpelo, Colombia, 27 Nov – 7 Dec 2006***

*Lead:* Sandra Bessudo (Fundación Malpelo).

*Participants:* Mishal Cohen (Fundación Malpelo), Graham Edgar (University of Tasmania), Alberto Rodriguez (INVEMAR), German Soler (Fundación Malpelo).

*Key results:* A quantitative baseline was developed for ongoing monitoring of sessile invertebrates, mobile macroinvertebrates, and fishes, including several endemic species, allowing comparisons of different marine management area strategies across the Eastern Tropical Pacific.

***Coiba, Panama, 19 – 30 Mar 2007***

*Lead:* Hector Guzman (STRI).

*Participants:* Juan José Alvarado (Universidad de Costa Rica/TNC), Odalisca Breedy (CIMAR/Universidad de Costa Rica), Angel Chiriboga (CDRS/Brown University), Jorge Cortes (CIMAR/Universidad de Costa Rica), Graham Edgar (University of Tasmania).

*Key results:* Data collected on the abundance of scleractinian corals, hydrocorals, octocorals, echinoderms, and fishes acts as a baseline for future threatened species monitoring, and will be used by Panama's environmental agency, ANAM, in their management plan for the marine protected area surrounding Parque Nacional Coiba. Sites outside the marine managed area

were also surveyed and monitoring stations established to provide an ecological contrast to protected sites.

## 6. Capacity Building

The primary capacity building activity of the ‘Extinction Resistance’ workplan has been to support Monica Calvopiña, a native of the Galápagos, in undertaking her PhD on the research topic of ‘extinction resistance of marine species’, out of the University of Tasmania. Her committee comprises PI Edgar (senior advisor) and PI Brooks, along with Jamie Kirkpatrick (University of Tasmania). She has an MSc in Marine Resources Development and Protection, from Heriot-Watt University, Edinburgh, and has previously worked with WWF and is the regional participant in the Marine Learning Partnership (“Effective Design and Management of Tropical Marine Protected Area Networks through Cross-Institutional Learning”). Her graduation is anticipated in December 2011.

The funding committed from MMAS for the “Extinction Resistance” project totaled \$420k. We estimate that we have been able to leverage \$980k of additional funding, from six sources. This includes support from ARC through the University of Tasmania for “Incorporation of Vulnerability and Irreplaceability into Marine Protected Area Planning”, totaling AUS\$345k (~US\$300k) over three years. PI Edgar is the PI, and PI Brooks and Jamie Kirkpatrick (University Tasmania) are Co-Investigators. This project builds from ‘Extinction Resistance’ with further tests of its concepts and results, with about one-third of this work focused in the Eastern Tropical Pacific region. This is wholly new funding, and is included as a formal match to MMAS. The project would not have been funded without MMAS involvement.

In addition to these new resources, the “Extinction Resistance” project synergizes with and leverages a number of other funding sources already in place in CI. These include: a) Walton Family Foundation, United Nations Foundation/Global Conservation Fund, and Darwin Initiative funding to CI- Galápagos for marine biodiversity surveys and monitoring in the ETPS; b) CI- Pacific program funding from the Gordon & Betty Moore Foundation, to support conservation science and planning through SPREP; c) GMSA funding for the Eastern Tropical Pacific fish workshop through IUCN/ODU; d) contributed staff time from the former Conservation Synthesis department within CI. The approximate annual value of these leveraged funds is as follows:

Source	FY06	FY07	FY08	FY09	Total
MMAS “Extinction Resistance”	\$175k	\$160k	\$85k	-	\$420k
ARC/University of Tasmania	-	\$60k	\$100k	\$100k	\$260k
Walton/CI-Galápagos	\$50k	\$50k	-	-	\$100k
UNF-GEF/CI-Galápagos	\$25k	\$25k	-	-	\$50k
Darwin Initiative/CI-Galápagos	\$35k	\$35k	-	-	\$70k
SPREP/CI-Pacific	-	\$95k	\$90k	\$90k	\$275k
IUCN/ODU GMSA	-	\$60k	-	-	\$60k

Conservation Synthesis	\$25k	\$90k	\$90k	\$10k	\$215k
<b>Total</b>	<b>\$310k</b>	<b>\$575k</b>	<b>\$365k</b>	<b>\$200k</b>	<b>\$1,450k</b>

### Appendix I: Abbreviations

ARC: Australian Research Council  
 CI: Conservation International  
 CIMAR: Centro de Investigación en Ciencias del Mar y Limnología  
 CDRS: Charles Darwin Research Station  
 CORDIO: Coastal Oceans Research and Development in the Indian Ocean  
 GCF: Global Conservation Fund  
 GMSA: Global Marine Species Assessment  
 INVEMAR: Instituto de Investigaciones Marinas y Costeras  
 IUCN: International Union for the Conservation of Nature  
 MMAS: Marine Management Areas Science  
 MNHN: Muséum National d'Histoire Naturelle  
 ODU: Old Dominion University  
 SPREP: South Pacific Regional Environment Programme  
 SSC: Species Survival Commission  
 STRI: Smithsonian Tropical Research Institute  
 UNAM: Universidad Nacional Autónoma de México  
 UNF: United Nations Foundation  
 WWF: World Wildlife Fund

CR: Critically Endangered  
 EN: Endangered  
 VU: Vulnerable

### Appendix II: Summary of progress against deliverables as proposed in original 'Extinction Resistance' workplan.

Deliverables	Date	Progress
Preliminary report of activities for first year, including initial indication of effectiveness of ETPS Marine Management Areas in conserving biodiversity.	Mar 2007	First (Sep 2006), second (Apr 2007), and third (May 2008) reports delivered.
Initial data compilation, including populated database on distributions, populations and trends of threatened and endemic species in ETPS Marine Management Areas.	Mar 2007	Database completed for Eastern Tropical Pacific corals, endemic fishes, and Galápagos endemic macroalgae.
Preliminary written summary of guidance to GMSA and ETPS teams on the design of standards and procedures for conducting red list	Jun 2006	Completed through data compilation process for Eastern Tropical Pacific species, and

assessments of marine species in the ETPS, and appropriate ways to monitor threatened and endemic species.		through field activities in Galápagos, Isla de Coco, Malpelo, and Coiba.
Compilation and submission to IUCN of report describing outcomes of Red List threatened species assessment workshops for corals and endemic macroalgae within the ETPS.	Mar 2007	Assessments for Galápagos endemic species (10 corals and 74 macroalgae) published on the 2007 IUCN Red List. Assessments for the 79 wider Eastern Tropical Pacific corals published on the 2008 IUCN Red List.
Database on status and trends of threatened and endemic species. Database to note occurrence inside MMAs and outside MMAs. This database to be compatible with Seascape plans coordinated through CI ETPS and PIP teams. Designed to be of optimal benefit for known species research efforts in the region, including for populating the SIS database for the GMSA.	FY09	World Biodiversity Database populated for the identification of 88 marine key biodiversity areas in the Eastern Tropical Pacific (32 of which are existing marine managed areas) and seven in Samoa (three of them existing marine managed areas).
Regional deliverables, one for each of the two regions, highlighting: 1) the coverage of MMAs on threatened and endemic species compared with surrounding areas and recommendations regarding future management of these existing MMAs in each region; 2) projections of future population trends, including probability of extinction; 3) assessment of the extent to which threatened and endemic species' critical habitats are protected within the MMAs; and 4) recommendations on how to better design and manage the ETPS and central Pacific (Fiji) MMAs. The most appropriate form of this deliverable will be determined based on consultations with ETPS and Fiji teams.	FY09	Two peer-reviewed scientific papers published for Eastern Tropical Pacific (Edgar et al. 2008 in <i>'Aquatic Conservation: Marine and Freshwater Ecosystems'</i> ; Edgar et al. 2009 in <i>'Global Change Biology'</i> ), and three more papers in preparation for submission to peer-reviewed scientific journals. Technical report on <i>'Priority Sites for Conservation in Samoa: Key Biodiversity Areas'</i> published for Samoa.
Compilation and submission to IUCN of report describing outcomes of Red List threatened species assessment workshops for endemic fishes within the ETPS, and endemic corals and fishes within the central Pacific (Fiji).	FY08 (ETPS), FY09 (Fiji)	Assessments for all 1,149 Eastern Tropical Pacific endemic fish species compiled for submission to the IUCN Red List. Assessments for all 737 Indo-Pacific coral species published on the 2008 IUCN Red List.
Final written summary of guidance to GMSA and ETPS and PIP teams on the design of standards	FY08	Effective documentation published as Polidoro et al. (2008) chapter in

and procedures for conducting Red List assessments of marine species in the ETPS and PIP.		the edited volume ' <i>Wildlife in a Changing World</i> '.
Final written recommendations to ETPS and PIP on how to monitoring protocols to monitor population levels of these species as part of the regional MMAS Core Assessments. Monitoring recommendations will include both ecological monitoring techniques using scientifically-trained personnel, and monitoring of large charismatic vertebrates using tourist sightings.	FY09	For Eastern Tropical Pacific, delivered through field activities in Galápagos, Isla de Coco, Malpelo, and Coiba, and through the development of the diver guide and logbook.
Global deliverable of a peer-reviewed publication on the contributions of existing MMAs on threatened and endemic species conservation.	FY09	Two peer-reviewed scientific papers published (Edgar et al. 2008 in ' <i>Aquatic Conservation: Marine and Freshwater Ecosystems</i> '; Carpenter et al. 2008 in ' <i>Science</i> '). An additional publication provided guidelines for bringing threatened species into MMA planning (Bass et al, in ' <i>Animal Conservation</i> ')
Global report, which may feed into another global report developed with other MMAS management effectiveness studies or another global report developed by a partner organization noted in the target audience list. This will be determined based on discussions within MMAS regarding deliverables for the other studies and based on consultations with global target audience groups.	FY09	Delivered through extensive contribution from the 'Extinction Resistance' project to the overall MMAS ' <i>Living with the Sea</i> ' science-to-action report.
Discussions and presentations with target audiences regarding results and what they mean for future management.	FY09	Underway through CI-Galápagos and CI-Pacific.
At least three peer-reviewed publications anticipated.	FY09	Five peer-reviewed scientific papers published as noted above; and three further manuscripts in preparation.

### Appendix III: Publications.