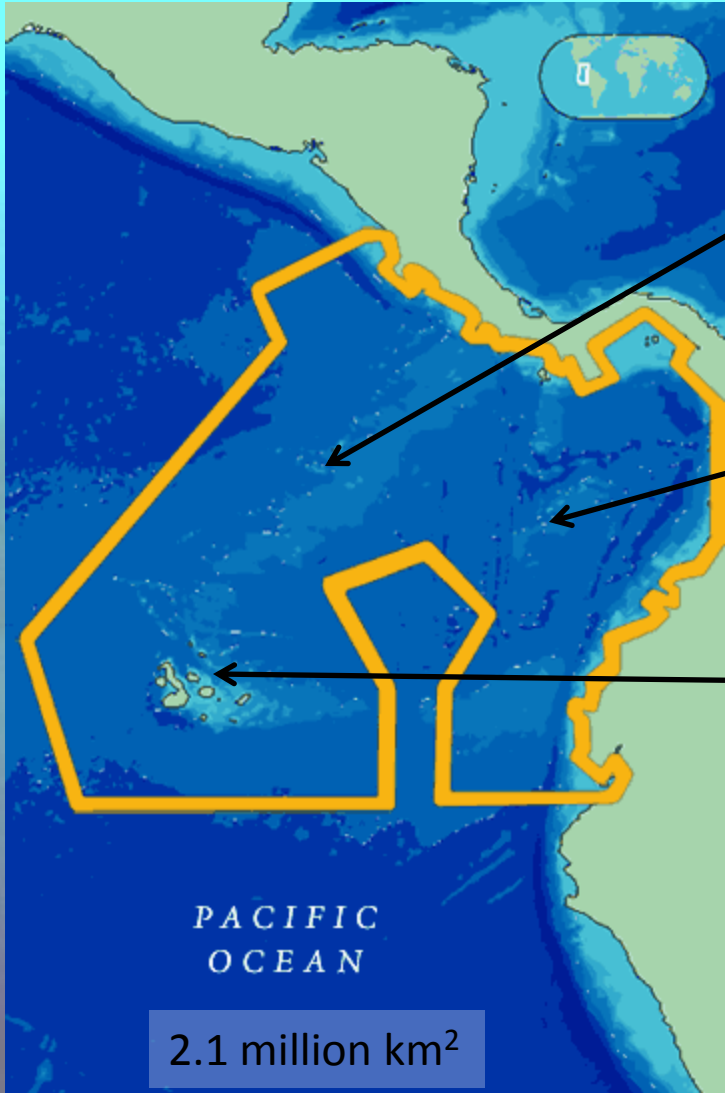


Inter-island movement of scalloped hammerhead sharks (*Sphyrna lewini*) in the Galapagos Marine Reserve and Eastern Tropical Pacific



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Background: The Eastern Tropical Pacific Ocean Seascape



Cocos Island (Costa Rica)



Malpelo Island (Colombia)



Galapagos Islands (Ecuador)

Also Coiba & Las Perlas (Panama)
Gorgona (Colombia)
Isla de la Plata, Machalilla (Ecuador)

Main threats: overfishing and El Niño Events

Justification: Research for Conservation

- Sharks are a key group in the marine ecosystem
 - Apex predators, drive natural selection processes
 - Distinct evolutionary group from bony fishes
 - Slow growth, late onset of sexual maturity, low fecundity – intrinsic characteristics which make sharks vulnerable.
-
- Recent studies have shown declines in shark populations in almost every single population studied
 - Ecological effects of top predator decline hard to predict but can be wide ranging (eg: Myers et al 2007).
-
- Sharks protected within MPA waters but fished illegally
 - Also fished outside protected areas
 - Finning by local fishers (Galapagos)



Focus: Research Questions

Nations encouraged to develop Shark Plans of Action to manage and conserve their shark populations

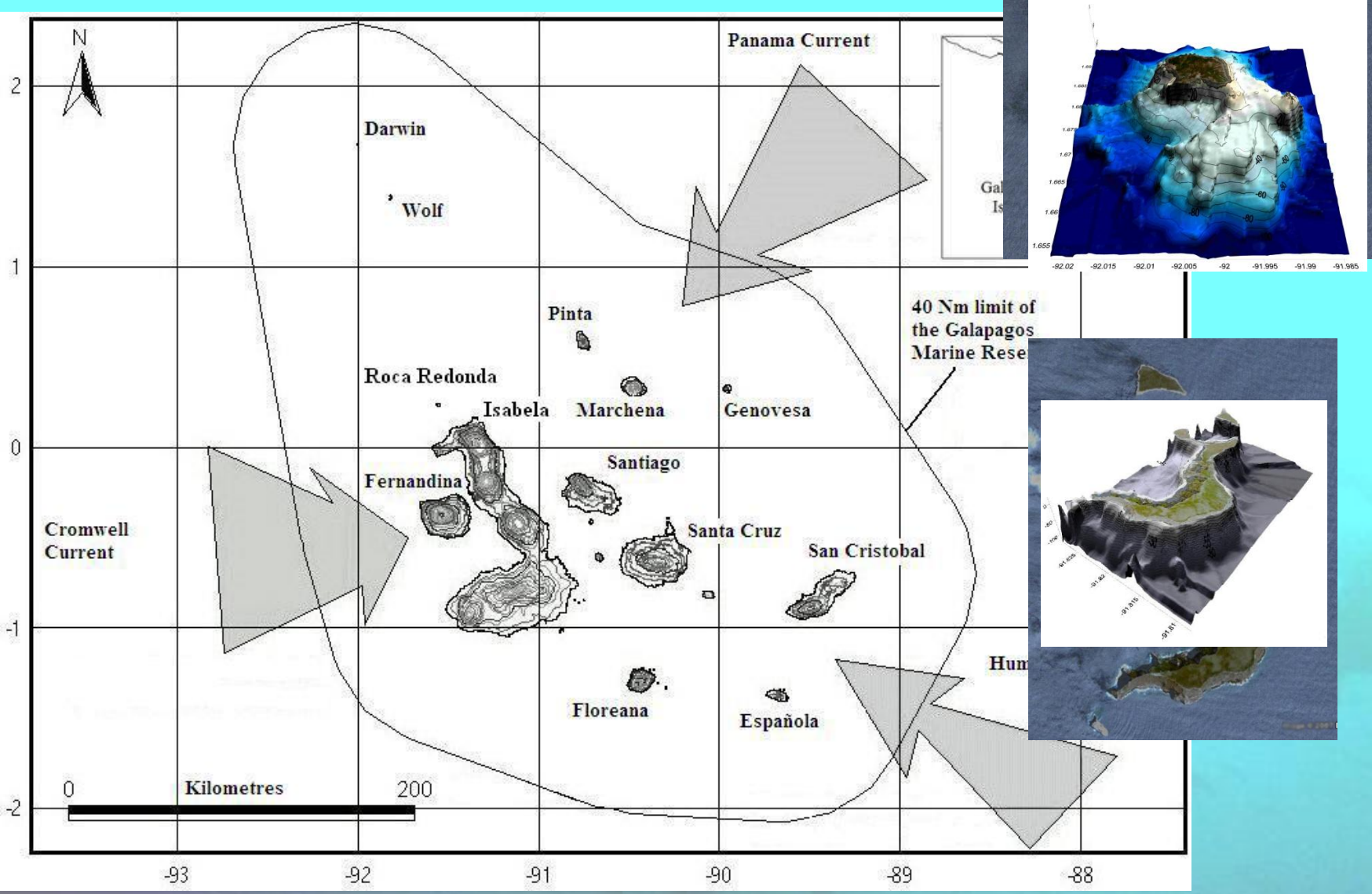
- How to delimit stocks?
- No baseline from which to follow trends

Do hammerheads display residency at particular sites?
Do hammerheads move between sites?
Do they display synchronous behavior?
Is their connectivity between MPAs on a regional scale?

What are the mechanisms behind site preference and migrations?



Focus: The Galapagos Islands: Darwin & Wolf



Shark tagging: Methods and Materials



VEMCO V16 coded tags. Emit train of pulses at 69 KHz.

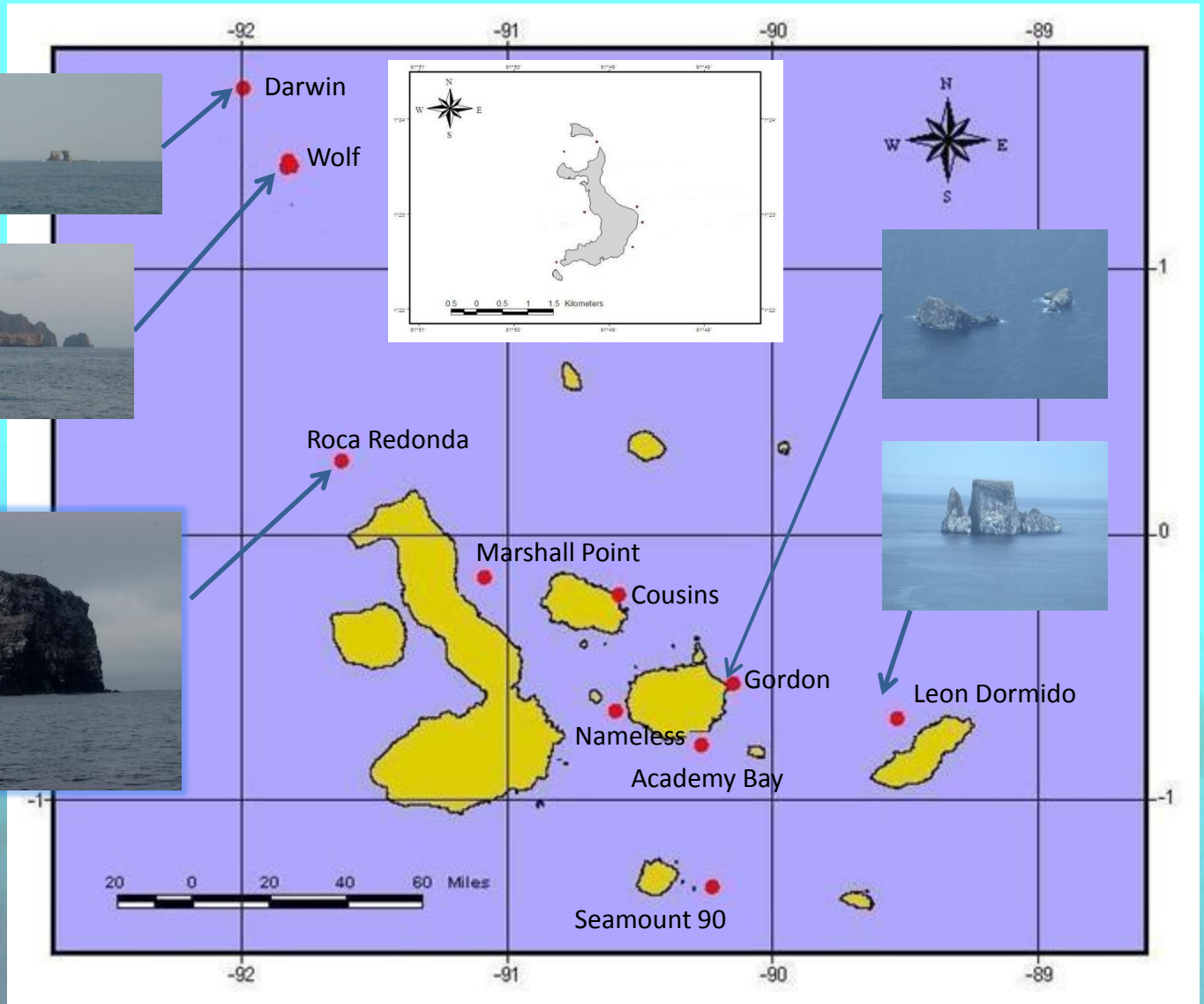


VEMCO VR2 listening stations (and temp logger), deployed on subsurface moorings

Tags are attached to darts and placed on pole spears. Free divers descend onto sharks and insert tag behind the dorsal fin, at a distance not greater than 50 cm from the shark.



Ultrasonic listening array in Galapagos

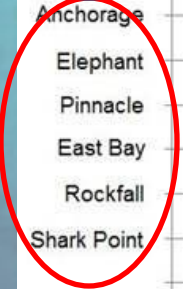
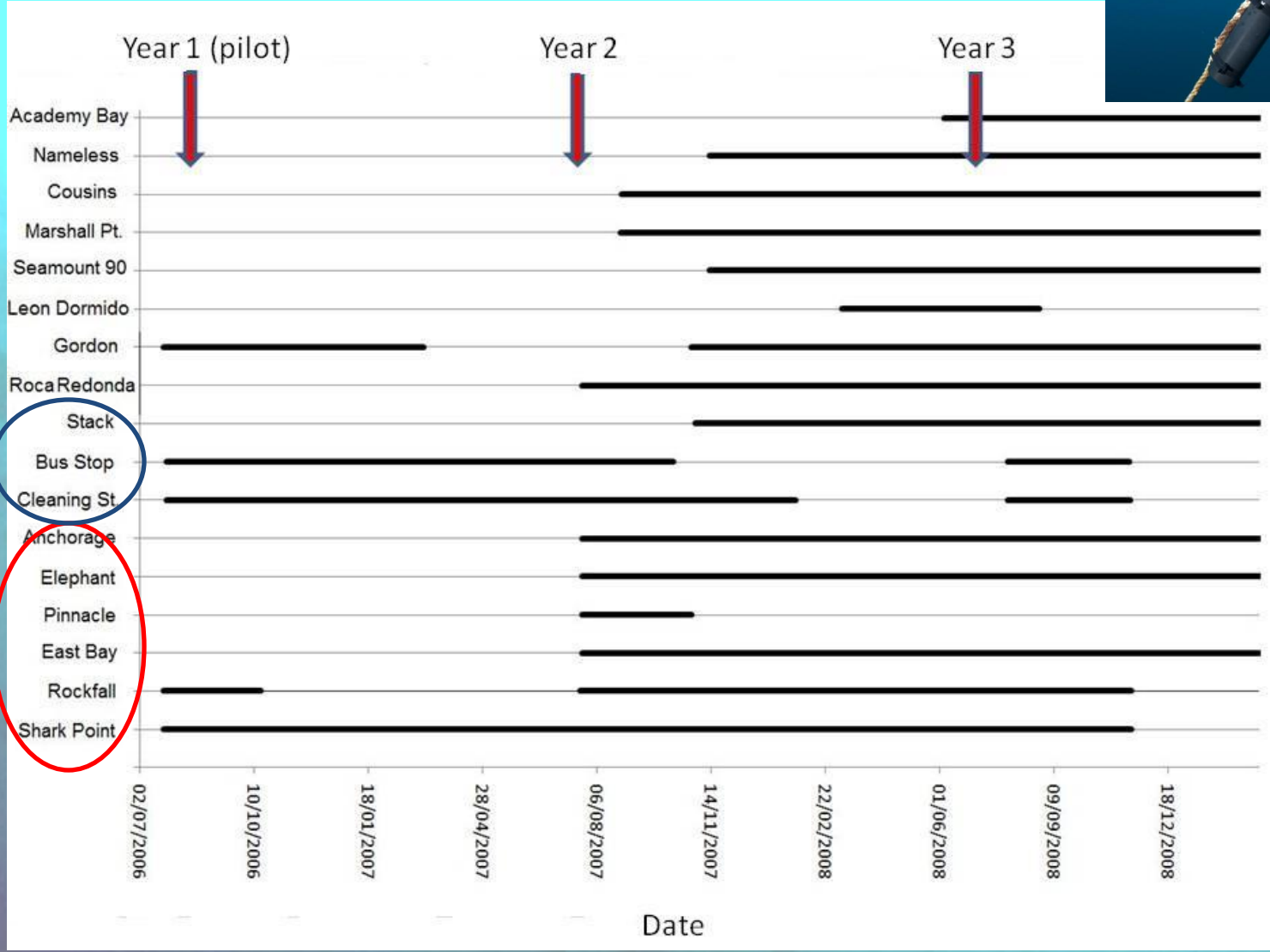


Results: Monitor Deployment

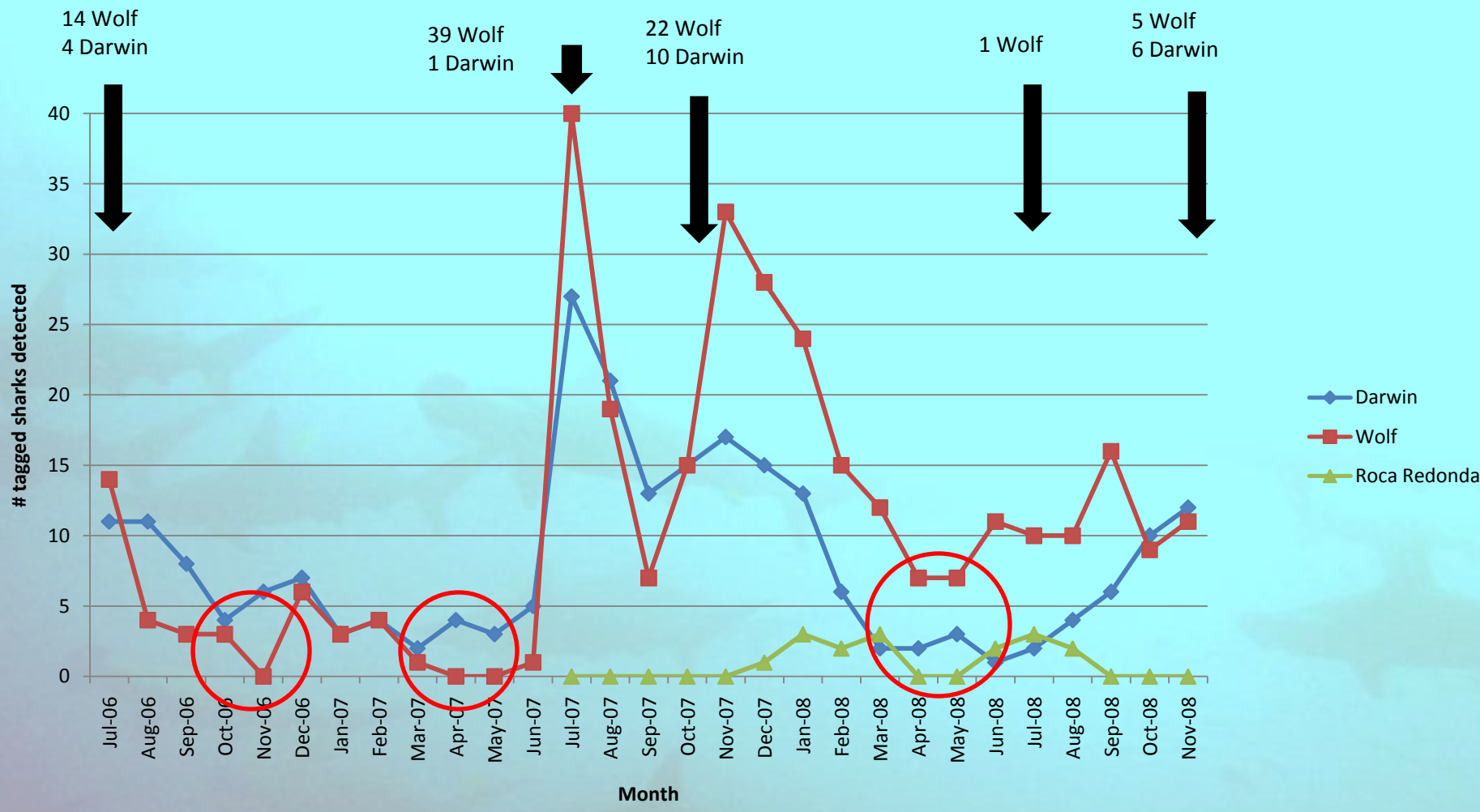


Darwin

Wolf

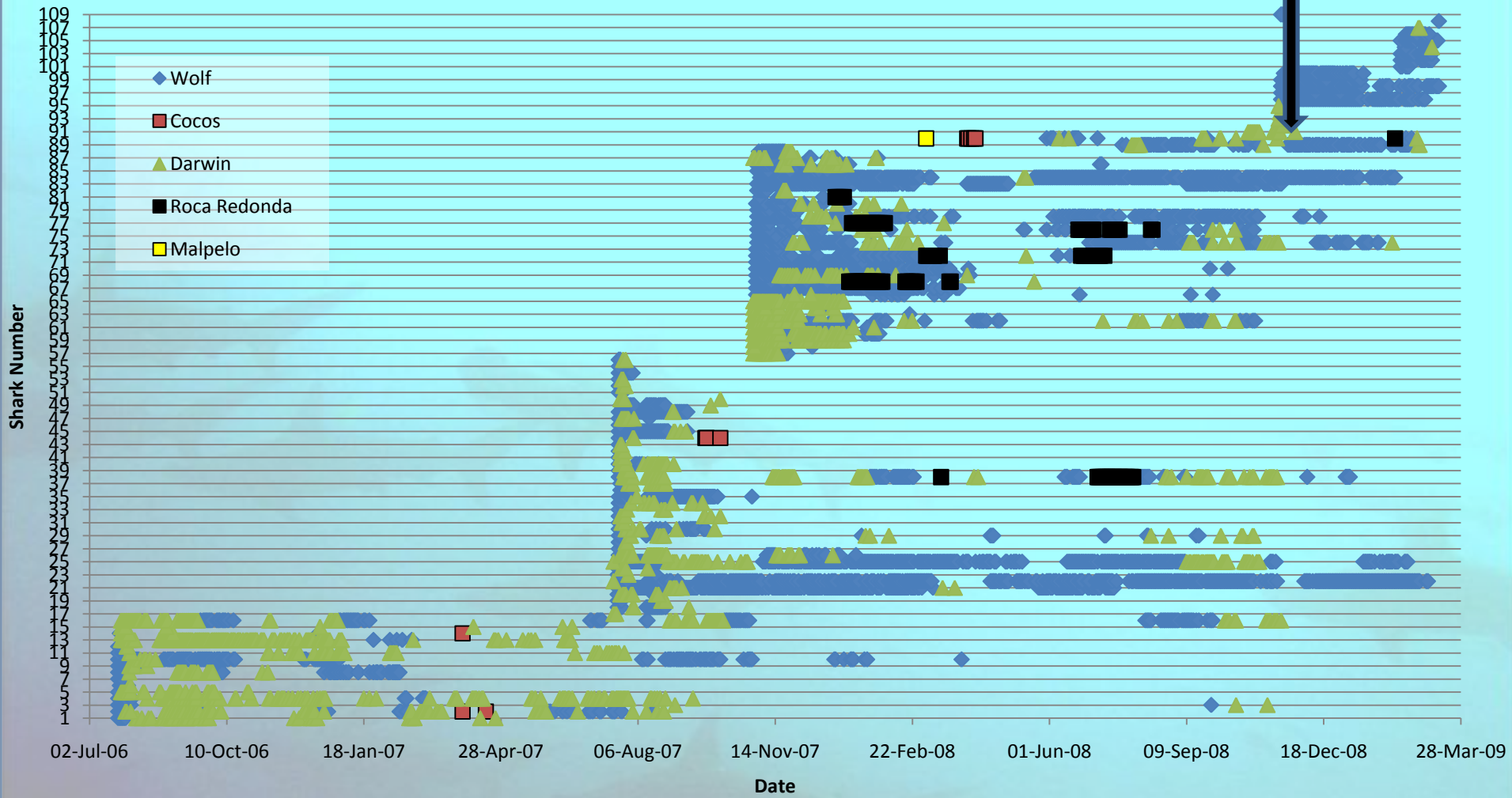


Results: Monthly presence at islands

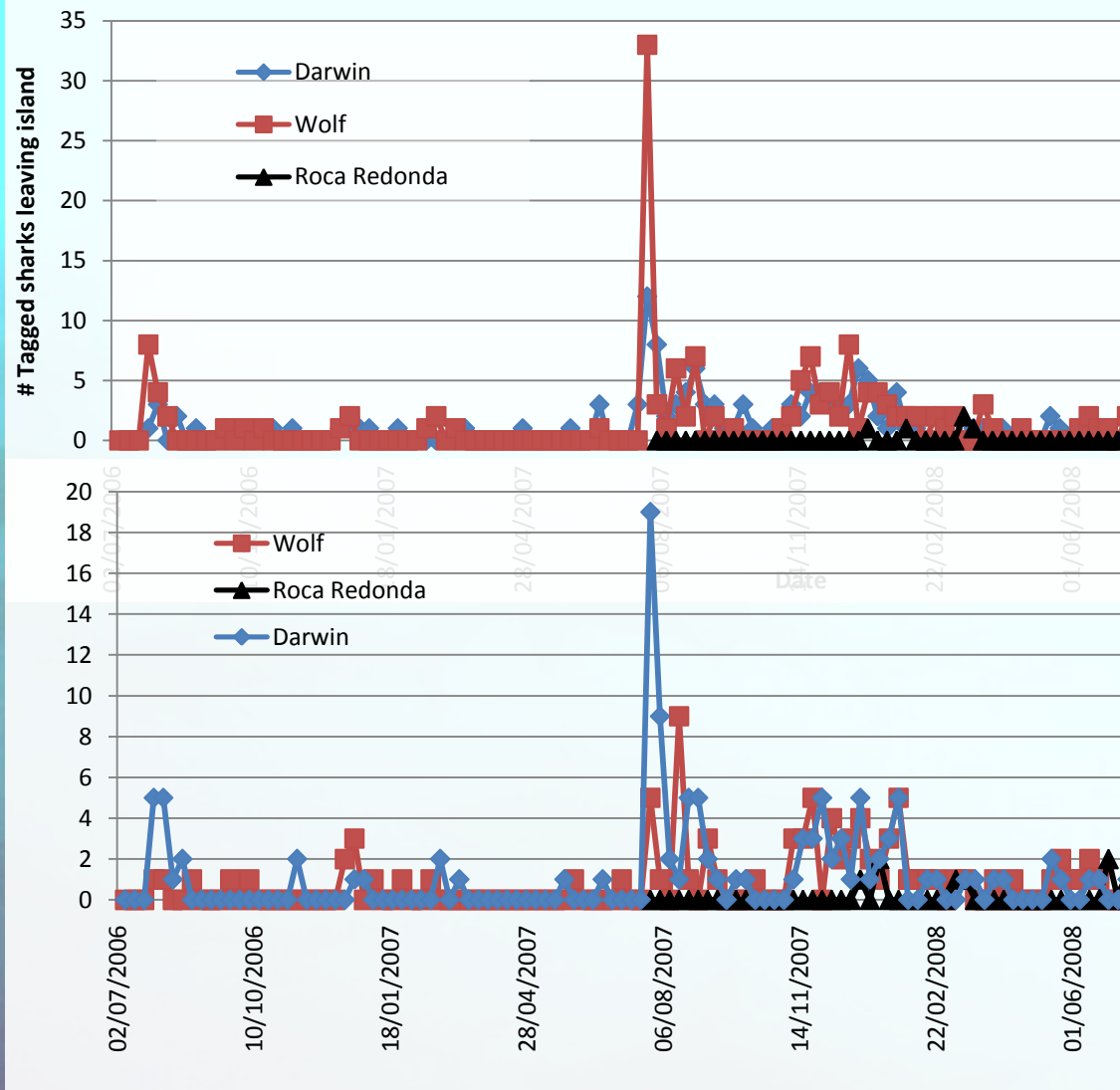


Results: Daily movements

Loss of Darwin Arch Monitors

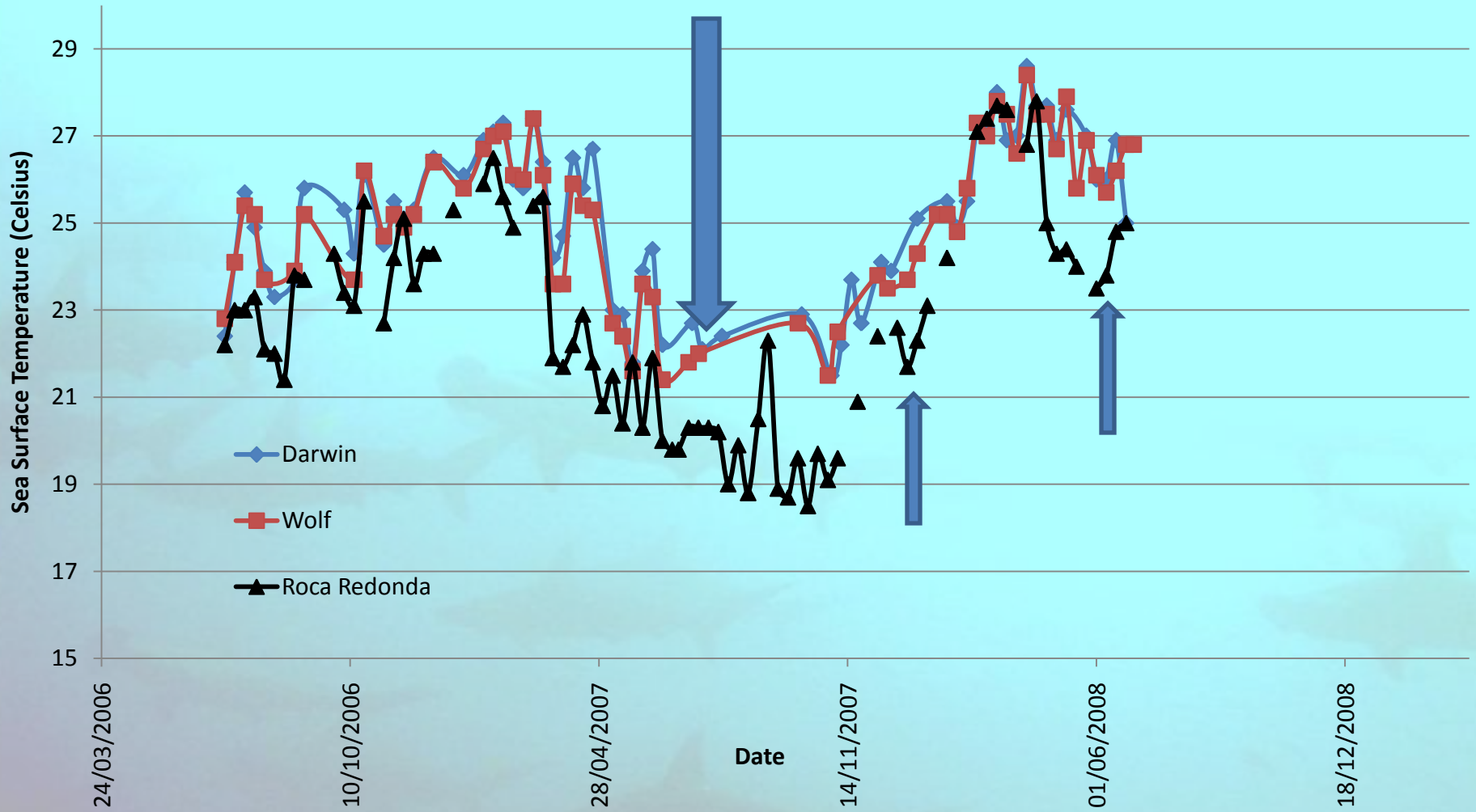


Results: Inter-island movements



23/07/2007 12:04	43:16:00
23/07/2007 15:48	23:30:00
23/07/2007 16:02	26:36:00
23/07/2007 16:45	17:56:00
23/07/2007 16:53	21:49:00
23/07/2007 17:26	19:43:00
23/07/2007 17:37	21:05:00
23/07/2007 17:40	25:21:00
23/07/2007 17:45	71:36:00
23/07/2007 17:52	39:42:39
23/07/2007 18:21	16:20:00
24/07/2007 13:08	77:58:00
24/07/2007 13:20	225:04:00
24/07/2007 14:22	19:17:00
24/07/2007 20:16	43:24:00
24/07/2007 20:27	17:59:00
24/07/2007 21:25	131:42:00
24/07/2007 23:30	83:12:00
24/07/2007 23:32	165:57:00
25/07/2007 01:56	701:51:00
25/07/2007 13:25	173:47:00
25/07/2007 20:55	59:11:00
25/07/2007 22:20	177:48:00
25/07/2007 22:35	15:43:00
28/07/2007 16:37	168:32:00
28/07/2007 22:44	16:04:00

Results: Sea Surface Temperature (weekly from AVHRR)



Emigration during upwellings?

Results: Average migration rates

- Of 61 hammerheads tagged at Wolf (2007), only 14 were not detected at a different island
- The remaining 47 undertook 113 interisland movements
 - 1 to Cocos Island
 - 8 to Roca Redonda
 - 65 to Darwin
 - 39 to Wolf (return trips)

	Wolf-Darwin	Darwin-Wolf	Darwin-Cocos	Wolf-RR	RR-Darwin	RR-Wolf
Number of trips	61	38	1	8	4	1
Mean travel time	293:08:37	471:53:37	1247:18:00	263:59:23	1143:18:42	350:44:00
StDev	48.59	31.29		4.48	18.35	
Max travel time	9055:49:00	3455:54:00	1247:18:00	465:58:00	1506:59:48	350:44:00
Min travel time	12:09:00	11:56:00	1247:18:00	169:22:00	569:58:00	350:44:00
Distance (km)	38	38	700	124	160	124
Max straight line speed (ms ⁻¹)	0.87	0.88	0.16	0.20	0.08	0.10

Results: Regional Connectivity

- Three sharks from Galapagos migrated to Cocos (one also returned)
- Three sharks from Malpelo migrated to Cocos (one continued to Galapagos)
- No apparent connection Galapagos north vs. Galapagos centre
- Connectivity with coastal areas?

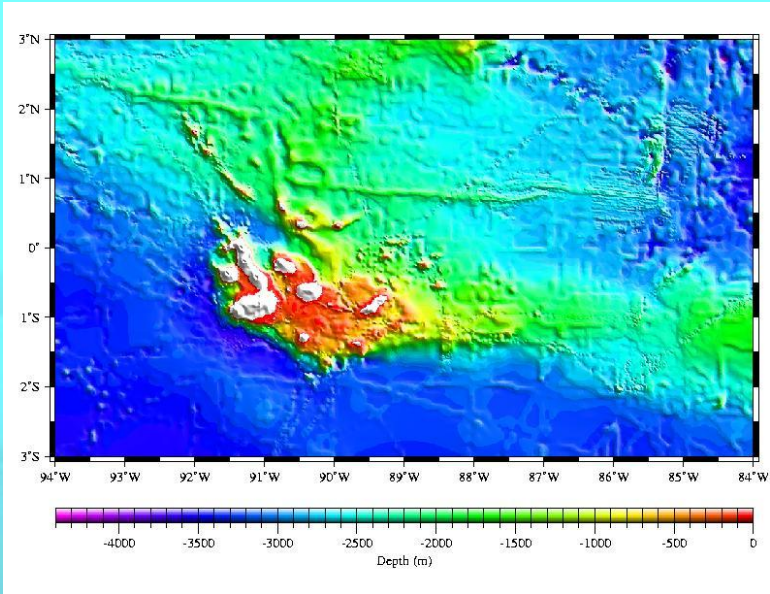
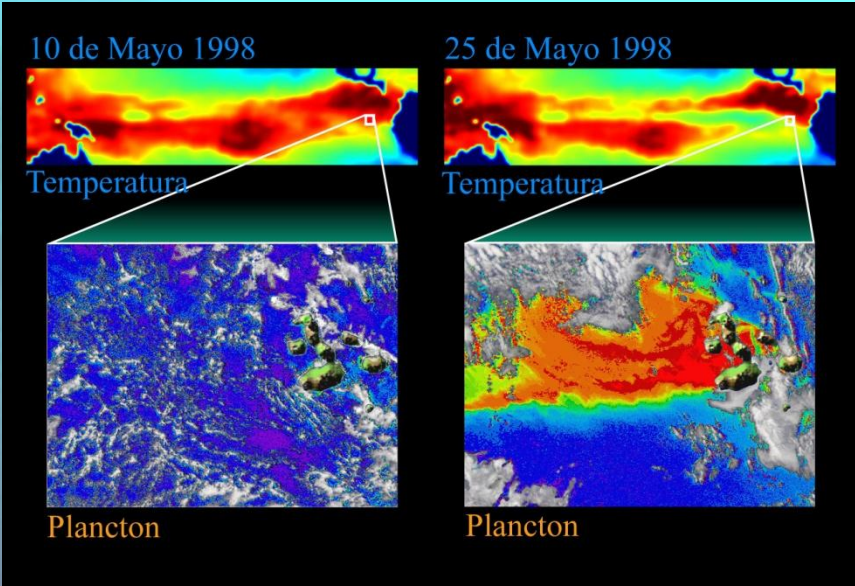


Discussion: mechanisms?

Galapagos highly dynamic (eg. Conditions in 1997-8), and complex biogeography

Complex bathymetry – chain of seamounts SE of Wolf... Deep sea in West

Currents? Temperature? Food availability? Reproduction?



Conclusions

- Hammerheads make constant movements between Darwin and Wolf islands. These are mostly carried out over a few days, suggesting that they may linger at open water sites for up to a few days (foraging)?
- Hammerheads seem to take a long absence from Galapagos in March-May.... This coincides with some detections at Cocos.
- Overall, connectivity in the region seems to exist, but at a low level (a handful of individuals have been detected at more than one MPA).
- Evidence for some migration synchronicity (2 sharks arrive at Cocos same day, many sharks migrate to Darwin within one hour, several sharks at RR at the same time).
- Temperature may be a factor... Food related?
- NO connectivity with the rest of the archipelago.



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