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Research Article

Odonate diversity reflected by wetland quality in Gujarat, India

SANJAY DHOLU[1], DARSHANA M. RATHOD[2]* and BHAVBHUTI M. PARASHARYA[1]

[1]*AINPVPM: Agricultural Ornithology, Anand Agricultural University, Anand – 388110, Gujarat, India*
[2]*Swarrnim College of Agriculture, Swarrnim Startup and Innovation University, Gandhinagar – 382422, Gujarat, India*
**Corresponding author E-mail:* darshanarathod500@gmail.com

ABSTRACT: Odonate diversity reflected by wetland quality was carried out on three riverine wetlands (Fazalpur, Sankarda and Sindhrot) of Vadodara district in Central Gujarat during 2014-15. The value of Dissolve Oxygen (DO) and Biological Oxygen Demand (BOD) was highest and the values of Electrical Conductivity (EC), Chemical Oxygen Demand (COD) as well as total solids in the water were lowest at Fazalpur as compared to other sites. Sankarda Point was slightly more polluted than Fazalpur with a marshy habitat structure which is ideal habitat for Odonates. Odonates diversity was evaluated during September and October at eleven wetland sites around Anand and correlated with water quality parameters. Maximum species richness and species diversity index were recorded at Pariej tank which was the least polluted point. Minimum species richness was observed at Navagam Canal 2 (8 Species) and Canal 1 (10 species) all having huge loads of industrial effluents. The correlation coefficient between the water quality parameter and diversity index (H') showed that pH had a significant moderate positive correlation (P < 5.0, df. 9) and BOD_3 had a significantly higher positive correlation (P < 1.0, df. 9). EC, Total Suspended Solids (TSS) and Total Solids (TS) had negative correlation with Odonate diversity**.** COD and Total Dissolved Solids (TDS) exhibited weak negative correlation with Odonate diversity.

KEYWORDS: Central Gujarat, damselfly, dragonfly, inventory, water quality parameters, wetland quality

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INTRODUCTION

Odonates are found near the proximity of various freshwater ecosystems, i.e., rivers, streams, marshes, lakes, water pools and rice farms. Odonates are good bioindicators and biocontrol agents. They can sense the difference in the ecosystem (Tiple *et al*., 2008). Dragonfly and damselfly like to reside near freshwater, uncontaminated and fully oxygenated surroundings. Due to this reason, they are known as a very useful indicator for ecology studies (Hilton, 1985; Lehmkuhl, 1976; Morin, 1984; Needham *et al*., 2000).

As an indicator of ecosystem health the species assemblages of Odonates are influenced by aquatic and terrestrial vegetation (Remsburg and Turner, 2009). Since larvae and adult Odonates respond to changes in habitat quality, they are globally acknowledged indicators for the check of marshland wellness (Samways, 1992). Dragonflies and damselfly endure in a broad ranch of underwater territory and are vulnerable to locality fluctuations caused by anthropogenic modifications. Suhling *et. al*. (2006) found that Odonates have been presented as indicators to impose the soundness of lakes, streams and reservoirs (Suhling *et. al*., 2006). Hence, they act as responsible species in biological diversity preservation (Lambeck, 1997; Noss, 1990) and characterize distinct living aquatic groups.

Human interferences such as the building of dams, unloading of streams, cultivation of crops, city and disposal of industrial gas and riverine forest cutting have created deterioration of underwater life and deprivation of freshwater biodiversity globally, principally in equatorial Asia and involve the Western Ghats (Dudgeon, 1994, 2000; Molur *et al.,* 2011; Subramanian, 2010).

Odonate community has been considered as an indicator of stream ecology (Norris and Norris, 1995). Freshwater macro vertebrates (including the Odonate community) are extremely menace taxonomic category (Darwall and Vie, 2005) due to their super sensitivity to the significant and subjective change of underwater behaviour (Laffaille *et al.,* 2005; Kang *et al.,* 2009; Sarkar *et al.,* 2008). Being an important part of the food chain, this day biodiversity and related regulation is a big question (Dudgeon *et al.,* 2006). Protection attempts to ease the impact of the load have mainly been laggard and lacking and because of that large number of the species are descending fast. The present study was conducted to monitor population dynamics with reference to water quality parameters and Odonate diversity of wetlands of different quality in Central Gujarat.

Odonate diversity of Gujarat state was studied by Rathod (2017) and Prasad (2004). Predatory potential and feeding capacity were studied in Gujarat (Rathod and Parasharya (2014, 2015). Forty-six species of dragonfly and damselfly were reported from Nalsarovar Bird Sanctuary- a Ramsar site in Gujarat (Rathod and Parasharya, 2018). The diversity of dragonflies and damselfly were reported from Central Gujarat (Rohmare *et al.,* 2015, 2016). He also studied the population dynamics of Odonates on three microhabitats of wetland and demonstrated that there was slight variation in species assemblage and community structure. However, his distinction of wetland microhabitat was purely qualitative. Rathod *et al.*, (2016, 2021) reported Odonates from protected areas and Dang Forest of Gujarat. Fifty-five species of dragonfly and damselfly were reported from the Southern areas of Gujarat (Rathod *et al.*, 2016). Studies on Odonate diversity in the wetlands with reference to its habitat quality parameters (both biotic and abiotic) were not done in Gujarat. To enable us to use Odonate diversity as a tool in biocontrol programmes and to assess wetland quality, this investigation was planned.

MATERIALS AND METHODS

(i) Odonata diversity and community structure of a wetland was studied by the point count method.
(ii) At least one count with intensive collection was done during August/September.
(iii) A study was done on at least five wetlands of different quality.
(iv) Specimens were collected and preserved for confirmation of identification.
(v) Water samples were collected for analysis once during October along with the Odonate count.

General inventory of odonata

Sampling

Adult, free-flying dragonfly and damselfly samples were captured from the mentioned places with the use of an insect net of 30 cm radius. Collections were made from all the wetlands under study. Captured dragonflies and damselflies were stored in paper envelopes which are commonly utilized by butterfly collectors. A broad-mouth plastic jar/container was used to keep them alive, as the pigmentation of mature vanishes or turns dull after storage, it is more important to take photos of the adult from every angle for identification. After photography and identification, the specimens were killed using a killing jar. Dead specimens were preserved dry or wet (70% alcohol) as per the requirement.

Identification

Identification of dragonflies and damselflies which were not able to be confirmed at field level were collected. The collected specimens were imaged and later identified with the help of taxonomic keys (Fraser 1933, 1934 and 1936; Subramanian 2009; Nair 2011). Later the species identification of the specimens was confirmed by a taxonomist Dr. S. S. Talmale of the Zoological Survey of India (Jabalpur, Madhya Pradesh).

Water quality parameters

At all the sites, the following water quality parameters were studied.

- pH was measured by digital pH meter.
- Conductivity was measured by a Conductivity meter.
- Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Chloride (Cl), Calcium (Ca), Magnesium (Mg), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were analysed by using standard method (Trivedi and Goel, 1984; Singh *et al*., 2005 and Maiti, 2011).

The water quality parameters were measured/analyzed at the Department of Agriculture Chemistry and Soil Science Laboratory of BACA, Anand Agricultural University, Anand, Gujarat, India.

RESULTS

Comparison of Odonate diversity with reference to wetland quality parameters

Wetland types:

- River (Mahi), River Tributary (Sankarda)
- Village Tank with domestic sewage (Jahangipura and Lambhvel)
- Village Tank with domestic sewage and industrial effluents (Navagam), Effluents Canals (1 and 2)
- Medium size Tank - Industrial effluents (Chalindra)
- Large size Tank - Industrial effluents (Bherai)
- Large size Tank - Canal water, least polluted (Pariej)

Table 1. Odonates diversity indices* at eleven study sites and respective value of water quality parameters

Sites	Species Richness	Diversity Index	Evenness	pH	EC (dS/m)	DO (mg/l)	BOD_3 (mg/l)	COD (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	HCO_3 (mg/l)	TS (mg/l)	TDS (mg/l)	TSS (mg/l)
Fazalpur (Natural drainage water and little polluted)	13	2.00	0.78	7.75	0.499	5.36	1.00	15	20	24	63.9	268.4	400	200	200
Sankarda, Least Polluted (Natural drainage, Rural sewage and Industrial effluents)	16	2.15	0.78	7.51	0.809	4.83	0.60	20	30	24	120.7	244	800	400	400
Sindhrot, Highly Polluted (Industrial effluents)	14	1.81	0.68	6.98	1.893	4.36	0.54	25	48	39.60	319.5	268.4	1400	800	600
Jahangirpura Village Pond (Rural sewage)	15	2.05	0.76	7.50	0.738	5.03	0.74	10	26	33.60	71	195.2	600	400	200
Lambhvel Sewage Pond (Urban sewage)	14	2.02	0.76	7.31	1.626	3.96	0.47	2	50	64.80	170.4	780.8	1400	1000	400
Navagam Village Pond (Rural sewage and Industrial effluents)	12	1.80	0.73	7.29	1.170	1.68	0.68	5	50	8.40	191.7	268.4	1200	600	600
Bherai Irrigation Tank (Industrial effluents)	17	2.50	0.88	7.22	0.995	3.02	1.81	15	40	12	142	268.4	800	600	200
Chalindra Village Tank (Industrial effluents)	12	2.16	0.87	7.31	1.550	3.02	2.02	13	40	24	234.3	317.2	1200	600	600
Navagam Canal1 (Industrial effluents)	10	2.03	0.88	7.41	2.060	1.34	0.80	7	30	24	276.9	512.4	1600	800	800
Navagam Canal 2 (Industrial effluents)	8	1.98	0.95	7.49	1.887	1.48	0.88	9	36	22.8	255.6	512.4	1400	600	800
Pariej Irrigation Tank (Mahi Canal Water and Least pollution)	22	2.71	0.88	8.43	0.241	3.76	1.78	-	-	-	-	-	310	155	155

Odonate diversity

Odonate diversity was evaluated during September and October at eleven wetland sites around Anand. Water quality parameters were evaluated during mid-October; the values are shown in Table 1.

The maximum species richness and species diversity index were recorded during the period at Pariej tank followed by Bherai tank and Sankarda (Table 1). Minimum species richness was observed at Navagam Canal 2 (8 Species) and Canal 1 (10 species) followed by Chalindra and Navagam village Tank (12 species) all having huge loads of industrial effluents. Village ponds having sewage showed a moderate number of species.

The minimum value of the species diversity index was recorded on the sites having a heavy load of industrial effluents, i.e., Navagam village pond followed by Sindhrot and Navagam Canal 2.

The evenness value of diversity varied between 0.68 to 0.95. The significance of its value depends upon the species richness and diversity index of the respective wetlands.

Water quality

pH: The pH value of the sites ranged between 6.98 (Sindhrot) to 8.43 (Pariej irrigation tank).

EC: The EC value was minimum at Pariej tank (0.241 dS/m) and Fazalpur (0.499 dS/m) and maximum at Navagam Canal 1 (2.060 dS/m).

DO: The DO value varied between 1.34 mg/l (Navagam Canal 1) to 5.36 mg/l (Fazalpur). Though both the sites had flowing water, the unpolluted Mahi River had the highest DO and the highly polluted Navagam Canal 1 had the lowest DO value.

BOD_3: The value of BOD_3 was high on large irrigation tanks (Pariej and Bherai). At the remaining sites, their values were less than one (<1.0), indicating that they have relatively less life.

TS: The value of TS ranged from 310 mg/l (Pariej irrigation tank) to 1600 mg/l (Navagam Canal 1). The TDS value varied from 155 mg/l (Pariej irrigation tank) to 1000 mg/l (Lambhvel sewage).

Correlation between Odonate diversity and water quality parameters

The correlation coefficient between the water quality parameter and diversity index (H') showed that pH had a significant moderate positive correlation ($P < 5.0$, df. 9) and Biological Oxygen Demand (BOD_3) had a significantly higher moderate positive correlation ($P < 1.0$, df. 9). Electrical Conductivity (EC), Total Suspended Solids (TSS) and Total Solids (TS) had moderate negative correlation with Odonate diversity**.** Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS) had weakly negatively correlated with Odonate diversity. The Dissolve Oxygen (DO) did not show any linear association with Odonate diversity. Both pH and BOD_3 showed significantly more positive correlation with the diversity index compared to species richness values (Table 2, Figure 1).

The correlation coefficient between the water quality parameter and species richness showed that pH and DO had a moderate positive correlation with the Species richness (S). The BOD showed a weak positive correlation. The TSS had significantly higher strong negative correlation ($P < 1.0$, df. 9). Both EC had a significantly higher moderate negative correlation ($P < 1.0$, df. 9) and Total Solids (TS) had a significant moderate negative correlation with species richness ($P < 5.0$, df. 9). The TDS were weakly negatively correlated with species richness. COD did not show any linear association with species richness (Table 2, Figure 2).

Similarity Index

Similarity index of the wetlands amongst the group was worked out and it is shown in Table 3.

Table 2. Correlation between species richness and water quality parameters

Water quality parameters	Odonate diversity	Species richness
pH	0.645*	0.544
EC	-0.559	-0.739**
DO	0.101	0.523
BOD_3	0.746**	0.370
COD	-0.285	-0.096
TS	-0.587	-0.715*
TDS	-0.471	-0.480
TSS	-0.581	-0.806**
Level of Significance at 5% = ± 0.602 Level of Significance at 1% = ± 0.735		

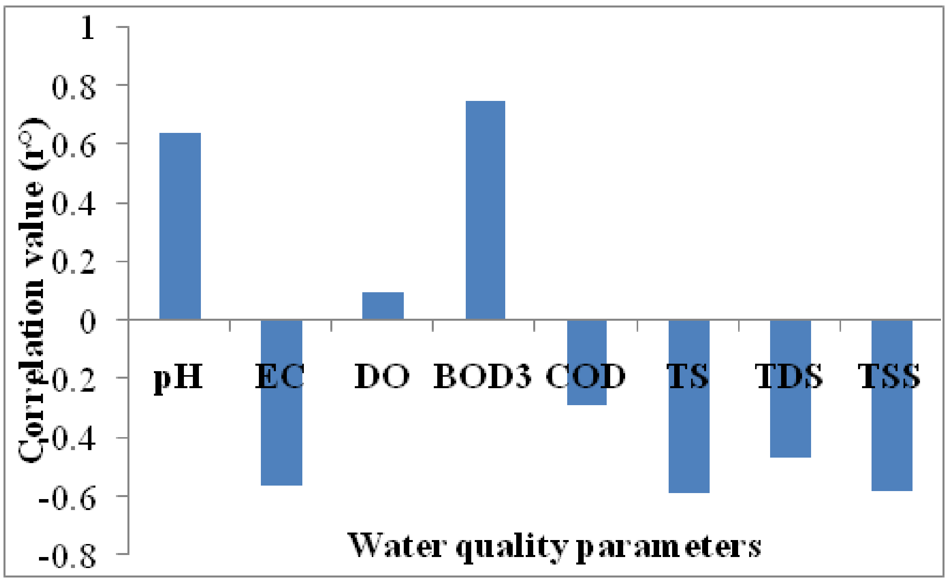

Figure 1. Correlation between Odonate diversity and water quality parameters.

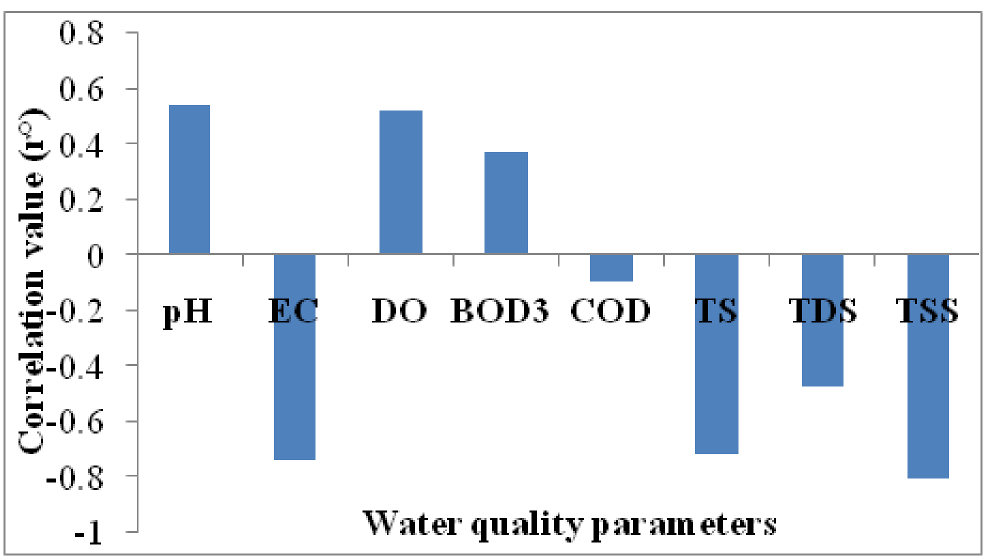

Figure 2. Correlation between species richness and water quality parameters.

It appears that wetlands having a similar physical structures or similar water quality parameters (Chemical structure) had higher values of the similarity index. Pariej Tank (least polluted) had the highest similarity index with Bherai Tank (0.82) having a similar large area with marshy habitat. This happened, in spite of the fact that Bherai had three times higher value of EC and TS than Pariej.

Both Pariej Tank and Fazalpur were the least polluted compared to the remaining sites. However, the similarity index between the two sites was just 0.63. This result indicates that water quality may not be the only factor determining species richness and its quality but the physical structure of the wetland might be playing an important role in determining species richness and overall community structure.

The similarity index amongst eleven wetlands varied from 0.50 (Lambhvel and Sindhrot) to 0.92 (Chalindra and Navagam). The differences in the similarity index were attributed to the differences in physico-chemical parameters of the wetland.

List of Odonates species collected from 11 different places

The intensive collections made in Anand, Vadodara and Kheda districts at eleven different places like Fazalpur, Sankarda, Sindhrot, Jahangirpura, Lambhvel, Navagam, Bherai, Chalindra Navagam Canal 1 and Navagam Canal 2 during September and 29 species (Dragonfly 18 and Damselfly 11) Table 4 Kheda district exhibited highest species richness.

DISCUSSION

Amongst eleven sites compared maximum species richness and species diversity index were recorded at Pariej tank having the least polluted water and marshy habitat and minimum species richness was observed at Navagam Canal 2 which has huge load of industrial effluents. Chakravorty *et al.,* (2014) showed that maximum species diversity at pond S was correlated with undisturbed or non-polluted situations and minimum species richness and species diversity frequently related to anthropogenic activities.

In the present study, all study sites had very low values of Dissolved Oxygen (1.34-5.36 mg/l) and hence the water was not ideal for any living organism. Karthika and Krishnaveni (2014) showed that DO levels were very low below the permissible limits and ranged from 1.7- 3.8mg/L in four wetlands of Coimbatore which was not ideal for any living organism while the permissible limit is 5 mg/L.

Patel and Parikh (2013) indicated that after winter the contamination burden is more protruding in contrast to further seasons on Mini River at Sindhrot, Vadodara. The acquired BOD rate indicates the pollution of water revealed a reduction in DO of the water; which infects the imperishable existence of flora and fauna in the river stream. The degradation in water properties may be due to a greater number of organic contaminants in the water.

In the present study pH, BOD_3 and DO were positively correlated with Odonate diversity and species richness whereas TS, TDS and TSS were correlated negatively with Odonate diversity and species richness. High value of TS and TSS alters macro-benthic fauna which is the food of Odonates. When the food of Odonates is negatively affected by water quality it has an augmented negative effect on the Odonate diversity of the respective wetland. The Lambhvel Sewage receives a huge quantity of domestic sewage containing detergent powder. Both TS and TDS had strong negative effects on species richness and species diversity.

Ishaq and Khan (2014) showed that the macrobenthic mass was correlated negatively with TS, TDS and TSS besides correlating positively with pH. The population of benthonic organisms residing in the Yamuna River was observed to be rising from October to May and afterwards slowly declining from June. Perhaps the rise during October to May is because of less turbidity, escalated transparency, minimum water velocity and more DO. The population of macro-invertebrates in the Yamuna River was observed to be at a low during the monsoon season (July–September). This can be described due to more turbidity, maximum TDS, high water velocity and less DO in the period of the monsoon season.

Langer (1980) showed that maximum floating materials reduce the level of photosynthesis by decreasing the perforation of light and heat yet benthonic organisms are as well much influenced by floating materials. It damages the bare respiratory parts of benthonic organisms and creates their displacement. This disruption in the food chain has a negative impact on developing Odonates which are predatory.

Large floating matters are connected with an expansion in invertebrate shift or movement (Gamon, 1970). For feeding invertebrates (Graham, 1990) illustrated that periphyton and reduce its attractiveness, maximum floating matter minimizes populations and affluence of benthonic organisms including Chironomus which are identified as resistance species are too susceptible to floating matter (Moran, 1998). Thus, a higher value of TS and TSS has a negative impact on macro invertebrates in general which also includes Odonates. Hence the result of present study is fully supported.

Nelson *et al*., (2000) studied that DO has a major impact on macro-invertebrate group formation. They suggested that the maximum DO level in an open water ecosystem is required for the fundamental development of the macro invertebrate community.

Table 3. Similarity index of Odonate species richness among different sites

Sites	Fazal-pur	Sankarda	Sindhrot	Jahangirpura	Lambhvel	Navagam	Bherai	Chalindra	Navagam Canal 1	Navagam Canal 2	Pariej Tank
Fazalpur	1.00	-	-	-	-	-	-	-	-	-	-
Sankarda	0.76	1.00	-	-	-	-	-	-	-	-	-
Sindhrot	0.81	0.87	1.00	-	-	-	-	-	-	-	-
Jahangirpura	0.64	0.64	0.55	1.00	-	-	-	-	-	-	-
Lambhvel	0.52	0.60	0.50	0.55	1.00	-	-	-	-	-	-
Navagam	0.72	0.78	0.69	0.67	0.54	1.00	-	-	-	-	-
Bherai	0.66	0.79	0.64	0.75	0.58	0.76	1.00	-	-	-	-
Chalindra	0.80	0.78	0.77	0.59	0.54	0.92	0.69	1.00	-	-	-
Navagam Canal 1	0.69	0.69	0.67	0.64	0.58	0.81	0.74	0.81	1.00	-	-
Navagam Canal 2	0.66	0.67	0.64	0.52	0.64	0.80	0.64	0.80	0.88	1.00	-
Pariej Tank	0.63	0.79	0.67	0.70	0.61	0.71	0.82	0.71	0.63	0.53	1.00

Table 4. List of Odonates species collected from 11 different places during September and October

Species Name	Fazalpur	Sankarda	Sindhrot	Jahangirpura	Lambhvel	Navagam	Bherai	Chalindra	Navagam Canal 1	Navagam Canal 2	Pariej	Total
Brown Spread-wing					P							P
Pigmy Dartlet	P	P	P	P	P	P	P	P	P	P	P	P
Coromandal Marsh Dart	P	P	P	P	P	P	P	P	P	P	P	P
Golden Dartlet		P		P	P		P				P	P
Common Blue tail	P						P					P
Pixie Dartlet	P	P	P	P		P	P	P	P		P	P
Senegal Golden Dartlet	P	P	P	P		P	P	P	P	P	P	P
Three Striped Blue Dart	P	P	P		P	P	P	P	P	P	P	P
Violet Striped Blue Dart			P									P
Blue Grass Dartlet					P						P	P
Saffron-faced Blue Dart	P	P	P									P
Rusty Darner					P							P
Blue-tailed Green Darner											P	P
Common Clubtail	P	P	P	P		P	P	P			P	P
Trumpet Tail	P			P	P						P	P
Little Blue Marsh Hawk		P		P		P	P				P	P
Ditch Jewel	P	P	P	P	P	P	P	P	P	P	P	P
Granite Ghost				P								P
Ruddy Marsh Skimmer	P	P	P	P	P	P	P	P	P	P	P	P
Black Ground Skimmer				P			P				P	P
Ground Skimmer		P			P	P	P	P	P	P	P	P
Crimson-tailed Marsh Hawk				P	P							P
Green Marsh Hawk	P	P	P	P	P	P	P	P	P	P	P	P
Wandering Glider		P	P		P		P				P	P
Common Picture Wing				P			P		P		P	P
Red Marsh Trotter							P				P	P
Crimson Marsh Glider		P	P								P	P
Long-legged Marsh Glider	P	P	P					P			P	P
Greater Crimson Glider						P		P			P	P
Total Species No.	13	16	14	15	14	12	17	12	10	8	22	29

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